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DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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MR. JOS. M. WILSON, President, in the chair.

VISCOSE AND VISCOID.*

BY CLAYTON BEADLE.

In August, 1894 (*Journal of the Franklin Institute*, Vol. CXXXVIII, No. 824), I had the honor of reading a paper before this Institute upon some new cellulose derivatives which had been discovered and partly worked out by my colleagues, Messrs. C. F. Cross and E. J. Bevan, and myself. Mr. Arthur D. Little, of Boston, took up the subject on this side of the water, and the samples which we showed you at that time were produced by him. Since then, we have added considerably to our knowledge of these derivatives. The basis of these products is a substance to which we

* Read by title.

have given the name "Viscose." Viscose is chemically cellulose xanthate, the preparation and constitution of which is fully explained and set forth in my previous paper (*vide ut supra*).

The dry regenerated cellulose obtained from the viscose solution we have named "Viscoid."

It is impossible, in a paper of this length, to give a history of all the work we have done in the last two years in connection with viscose; so I have chosen to confine myself to certain branches of the work, the description of which, I trust, will prove interesting to the members of the Institute.

MANUFACTURE OF ALKALI CELLULOSE.

In the manufacture of viscose on a large scale, we first endeavored to discover what materials could be utilized, and in the course of our work we found that any kind of cellulose could be used, provided that it was fairly pure. The fibers, however, should be very short indeed; the process depends as much upon the length of the fiber as upon the purity of the cellulose. As an instance of this, if raw cotton be used without any disintegration, it is almost impossible to mercerize it and convert it into viscose; but if the fiber be disintegrated so as to break up the ultimate fiber into pieces of about one-twentieth of the length of the original, the mercerization and conversion into viscose is rapid and complete. With regard to the purity of the fiber, bleached wood generally yields a better viscose than unbleached wood, but it is next to impossible to convert mechanical wood (*i. e.*, wood disintegrated by mechanical means, and containing a large amount of resin and other impurities) into viscose. The alkali cellulose often requires to be kept for several days before treatment with carbon bi-sulphide, but when the disintegration of the fiber is thorough and the mixture with caustic properly effected, the maturing of the alkali cellulose is almost unnecessary.

One great precaution, which at first we lost sight of, was to prepare the alkali cellulose without contact with the atmosphere.

This we discovered by analyzing a number of samples.

We found that on an average about 50 per cent. of the alkali had been carbonated during mercerization and thus rendered useless for the reaction. Alkali cellulose is converted by the action of the CO_2 of the atmosphere into sodium carbonate and cellulose without our knowing it. This change was the cause of a large number of failures, which necessitated conducting a series of trials under varying conditions, in which we determined the amount of alkali carbonated.

At last, we arrived at a method of producing the alkali cellulose by which only 5 per cent. to 10 per cent. of the total soda is converted into carbonate.

YIELD OF VISCOID.

A great deal of work has been done upon the amount of viscoid yielded by different celluloses. Pure cotton yields somewhat more than its own weight. This is due to a change in the cellulose molecule (*vide* Beadle, this *Journal*, Vol. CXXXVIII, No. 824). Wood, on the other hand, even when thoroughly bleached and pure, undergoes a considerable loss, which amounts often to 20 per cent. This is due to the formation of soluble products during mercerization.

We have followed this very carefully, and it appears that bleached wood pulp contains oxycellulose, which is largely dissolved by caustic soda. Under certain conditions the regenerated cellulose has no strength, as when films made from viscose solution are found to be rotten. Very great care has to be taken in the manufacture of viscose to insure that the regenerated cellulose is not injured by the treatment. A knowledge of this can be acquired only by experience, and those who are thoroughly acquainted with the manufacture of viscose can often tell at a glance, from the appearance of the alkali cellulose or the viscose solution, whether a satisfactory product will be obtained. These conditions are now well understood by us, so that we can insure that the cellulose is always regenerated in the proper physical condition required for the particular purpose to which it is to be applied.

PRODUCTION OF VENEERS.

Mention was made in my previous paper (*Journal of the Franklin Institute*, Vol. CXXXVIII, No. 824) of cutting pieces from the coagulum and annealing them under pressure for the production of sheets. This has been worked at on a larger scale. The viscose has been run into rectangular moulds, and the coagulation of the mass has been effected by exposure to a hot damp atmosphere. These masses, weighing from 250 to 400 pounds, have been dehydrated by exposing them to an atmosphere which is gradually raised in temperature. When the blocks have been sufficiently hardened they are cut into sheets about 24 x 18 inches, by a guillotine specially constructed for the purpose. By an automatic gear the bed on which the guillotine rested was made to travel forward at every stroke of the knife, and the amount of travel could be regulated at will, so that sheets of any thickness could be cut. By this means we were able to cut about twenty sheets per minute.

The sheets were deprived of the chemical by-products, and then submitted to heavy pressure, by means of which the cellulose hydrate was dehydrated down to a compact sheet of cellulose. We had a difficulty by this method in obtaining our dehydrated sheets free from structure. They had a tendency to split in laminæ. The fracture had every appearance of slaty cleavage (Beadle, *Chemical News*, London, Vol. LXX, p. 139), and the planes of cleavage were found always to be at right angles to the direction in which the pressure was applied. With thin sheets we had less trouble, and, I believe, the reason of this was that the sheet was thinner than the laminæ. In order to avoid this difficulty with thicker sheets, we were obliged to dehydrate the coagulum to a greater extent, by exposure to a hot atmosphere of steam before applying the pressure. The fact of pressure on the coagulum giving rise to slaty cleavage, prevented us from applying pressure for moulding solid articles from the coagulum. This is obvious when we take into consideration the fact that the dehydrated laminæ, formed on the outer surfaces by the first application of pressure, prevents

the egress of moisture from the interior, and, as it were, seals the interior from further dehydration. We found it next to impossible to mould articles of any thickness under pressure from the coagulum for this reason, even on the application of a pressure of several tons to the square inch. When, however, the sheets are almost dried by exposure to warm air, or by one of the processes described subsequently for the production of solids, they can be embossed and stamped into small articles, such as buttons, which are sufficiently structureless for all practical purposes.

When the sheets are completely dried they offer too great a resistance for moulding under pressure. Viscoid sheets can be produced by the above process in almost any color, either translucent or opaque, and they can be prepared in such a way that they are either soft and pliable, or stiff and horny like celluloid. Under pressure they can be embossed in various patterns.

PRODUCTION OF VISCOID.

For Use in Turning, etc.—Viscoid is prepared by coagulating the viscose in the same way as described above for the production of veneers or sheets, but the moulds are circular instead of rectangular. As might well be supposed, the difficulties of coagulating the viscose increase with the diameter of the cylinder. Great care has to be taken in the early stages to prevent the material from cracking. Immediately after coagulation takes place there is a considerable shrinkage, and unless the coagulation proceeds uniformly throughout the mass there is danger of it cracking. The time of coagulation increases with the diameter. The moulds in which the material is coagulated are specially constructed, and made of a material which is unaffected by the viscose, and the interior surface has to be such that the coagulum does not adhere to it, otherwise it is sure to crack on shrinking. After setting, the solid cylinders of coagulum are removed from their moulds. At this stage they are elastic and pliable, somewhat like rubber, but have to be handled with great care. They consist of about 15 per cent. of

cellulose, 7 per cent. of chemical by-products, and 78 per cent. of water of hydration.

Washing.—They are next placed in water for the removal of the by-products. We have done much work to determine the best conditions, and the cheapest and most effective method for getting rid of the by-products.

When the cylinders of coagulum are placed vertically in tanks provided with false perforated bottoms and immersed in water, the by-products are found to diffuse out and creep down the sides of the coagulum and to accumulate in the space below the false bottom. This action is so perfect, that often, when the water is undisturbed, the top portion contains only a trace of by-products and the lower portion is heavily charged with them. The removal of by-products is accelerated by the use of hot water. We find that the time required for the removal of the by-products varies as the square of the diameter of the coagulum. During washing, the coagulum undergoes a further shrinkage, so that when the washing is complete the coagulum contains about 20 per cent. of cellulose.

Drying.—The washed coagulum is next removed from the tanks and dehydrated or dried. The dehydration of the coagulum has presented us with some very interesting problems, which we have to a large extent solved. When the washed material is exposed to the air, it gradually contracts and loses weight, and this goes on until it is finally deprived of moisture, and nothing is left but the dry viscoid. We found it difficult to ensure that the material should retain its proper shape on drying. With "rack" or air drying at from 90° to 110° F., a solid cylinder remains flat at the ends, provided that the length is four times that of the diameter. If it is less than this, it has a tendency to become concave on the ends, and it becomes more concave up to a certain point as the length diminishes in proportion to the diameter. The sides of a solid cylinder have a tendency sometimes to become convex in proportion as the ends become concave. Unless drying is uniform, a cylinder of 1½ inches diameter and less, will bend less towards the driest side. With larger cylinders this is not so notice-

able. When cylinders are placed upon a rack that is not perforated, the top end contracts and dries the most rapidly, so that the cylinder becomes tapered towards the top. When the rack is perforated so as to allow of the free passage of air, the cylinder is sometimes found to be smallest at the bottom. Sometimes the cylinders are irregular in diameter or warped in final drying. During the process of drying, the coagulum is in a semi-plastic state, and, when the drying is uneven, is under considerable stress. The viscoid is caused to flow in the direction to relieve the stress, so that when finally dried and rigid, it is found to have assumed its original shape. It generally, however, leaves some marks of its temporary distortion. The time of drying, as far as our determinations have gone, varies as the square of its diameter.

When hot air is used, the rate of drying cannot be increased beyond a certain degree without serious injury to the solid. The solid, by constant exposure to hot air, becomes skin-dried, whilst the interior remains comparatively moist. The outer dried skin offers a great resistance to the passage of further moisture, and so the drying is very much retarded. If, under these conditions, the moisture is able to escape from the interior, the exterior being dry, and consequently rigid, offers great resistance to the contraction of the interior, and the consequence is that fracture often takes place. If the drying be not quite so rapid as to produce fracture, the interior is under tremendous stress, and when the cylinder is cut in section, cleavage often takes place in the direction of the length of the cylinder. When, however, the drying is conducted much slower, the moisture, which is always tending to pass from the wetter to the drier portions, finds a way of escape, and is removed from the surface by the atmosphere. We have been able to overcome these difficulties, and the product obtained is almost free from structure. The washed or unwashed coagulum has a natural inclination to contract when surrounded by a hot medium, even when the same has no drying capacity whatever. The rate of contraction increases with the temperature; thus, a coagulum contain-

ing 10 per cent. of cellulose will rapidly contract to about half its bulk on immersion in boiling water. When heated in this way there is no indication of case-hardening. There is a limit, however, to this contraction. We tried the effect of saturated steam at different pressures upon cylinders of washed coagulum, which contained about 15 per cent. of cellulose. The pressure was varied from 3 to 8 atmospheres; the time of exposure was one hour in each case. The average contraction was about 25 per cent. The experiments go to show that there is little or no difference between the 3 atmospheres or 8 atmospheres on the amount of contraction. As the diameter increases, the rate of contraction diminishes. The next set of trials were made to determine what effect time had upon the shrinkage in an atmosphere of saturated steam at 4 atmospheres. Taking the original weight as 100, after one hour's treatment, the weight became 82·9.

After two hours, the weight became	74·5
" three " " " "	65·7
" four " " " "	63·0

The above was on a piece of washed coagulum, containing about 15 per cent. of cellulose. We next took some unwashed coagulum, containing about 11 per cent. of cellulose, and suspended it in an atmosphere of saturated steam at 4 atmospheres. It lost 44·8 per cent. during the first hour; 14·7 during the second hour. Therefore, it had contracted during the two hours' treatment to 40·5 per cent. of its original weight. A receptacle was placed immediately beneath the coagulum to catch the by-products, which were found to be recovered without dilution. With blocks of double the diameter of the above, *i. e.*, 75 millimeters, the weight after two hours' treatment was 56·6 per cent. of the original. The effect of saturated steam is to produce a rapid contraction of the coagulum, if it contains from 10 to 15 per cent. of cellulose, and this contraction is rapid until a concentration of about 20 per cent. of cellulose is reached. By a prolonged treatment in saturated steam the coagulum gradually contracts until it contains about 25 per cent. of cellulose, beyond which point it does not alter.

IVORY-COLORED VISCOID.

Ordinary viscose has about the color and consistency of molasses, and yields a viscoid which has the general appearance of horn. We set to work to produce viscoid in imitation of ivory, and whilst doing this we discovered a new combination of viscose, which gave rise to a creamy white solution. This was found to last longer in the liquid form than the ordinary viscose. On drying down, it yielded a product which is a very fair substitute for ivory. It has a specific gravity of 1·8 to 1·85. We had several sets of billiard balls turned from this, and they were found to play very well, indeed. The angle, however, at which the balls left each other after striking was somewhat less than that of ivory balls. With the plain viscoid balls, which have a specific gravity of 1·5, the angle is greater than that of ivory, and we believe it possible to mix these two compositions in such a way that both the specific gravity and the angle at which they leave each other after striking resemble that of ivory. This "ivory" viscoid has been used for various articles, such as acorns for blind-cords, knife-handles, brush-backs, etc.

Viscoid for Electrical Work.—The plain viscoid was carefully tested to determine its insulating properties. It is about equal to vulcanized fiber for insulating purposes. It appears that if great care is taken to thoroughly remove the last traces of by-products, and to well season the viscoid, the insulating properties can be made much superior to vulcanized fiber. Cellulose, when completely deprived of moisture, is almost a perfect insulator, and its insulation diminishes as the hygroscopic moisture increases. Viscoid will probably replace vulcanized fiber to a large extent for electrical work, but at present it is very much inferior to vulcanite. It is likely that we shall find some means of improving it, so that it may be made to replace that substance.

Black Viscoid.—We next set to work to prepare an ebony-black viscoid, and after about six months' work we have obtained a uniform black viscoid, which in some respects appears to be superior to the plain substance. The ebony

viscoid will probably have a greater range of utility than any of the other products we have obtained. A jet black is preferable to white or any color for machine-tool handles, etc.

Blue Viscoid.—We have obtained a somewhat more expensive product very much resembling *lapis lazuli.* This is very nice for turning and carving, and takes a very high polish, and looks very well when made into fancy articles, such as umbrella and walking-stick handles.

Various Colors.—We have now got viscoid in a large variety of colors and shades, and have also succeeded in producing grained and mottled effects, which have a very pretty appearance when turned and polished. We see no reason why viscoid should not be used in place of celluloid for many purposes. Some samples have been kept two or three years and they do not discolor. Keeping the viscoid for a long time appears rather to improve it than otherwise.

PAPER SIZING.

Mr. Little mentioned this application of viscose in his paper (*Journal of the Franklin Institute*, Vol. CXXXVIII, No. 824). Viscose is now being extensively used in paper mills for this purpose. It does not size the paper in the sense that rosin does, although when viscose is used a large proportion of the rosin can be dispensed with. It is added to the beater, and a chemical substance is afterwards added which precipitates the cellulose among the fibers as a flocculent mass. The effect that it has upon the paper is, of course, dependent upon the amount used. It strengthens the paper from 30 to 100 per cent., and the paper produced with viscose, besides being much stronger, is also harder, has a better "feel" and rattle, and admits of a much better surface when calendered. It also assists in the retention of clay, and prevents the loss of short fibers which, as a rule, pass through the wire cloth of the machine. It therefore gives a larger output to the machine. It is chiefly used in the manufacture of "wrappings" and bag papers, but it is coming into use also for news and other papers. Where additional strength is not required, it

enables the paper-maker to use a lower-class and weaker fibrous material, without prejudicing either the strength or quality of his paper. By this means it decreases the cost of production. The precipitation of the cellulose requires a great deal of skill. Unless care is taken to ensure the right conditions, and to add the precipitating agents in the right proportions, the cellulose is precipitated as a non-adhesive mass, which gives neither strength nor hardness to the paper. It is necessary to know exactly the conditions of working in each mill before good results can be ensured, but when once these are known and understood there is no difficulty in obtaining uniform results.

THE NATURE OF HYGROSCOPIC MOISTURE IN CELLULOSE.

The behavior of viscoid on drying in the mass opened up some very interesting problems. It appeared to throw light upon the hygroscopic moisture of celluloses. I had previously observed (*Nature*, Vol. XLIX, No. 457) that the cotton fiber, when deprived of moisture (either by drying in an air bath at 105° C., or in a desiccator over sulphuric acid) and exposed to the air, rose in temperature rapidly for about eight minutes. It reached a temperature of about 4½° F. above that of the atmosphere, where it remained nearly stationary for a few minutes. It then fell gradually, and after about seventy minutes' exposure it again reached the temperature of the surrounding atmosphere. I endeavored to find what connection this had with the rate at which bone-dry cotton fiber assumed its hygroscopic moisture. I found that cotton fiber took about seventy minutes, and by weighing the cotton at different intervals, and comparing the rate of gain in weight with the rate of increase in temperature, I was led to the conclusion that the two were closely connected. The same experiments were repeated with anhydrous viscoid which had been ground to a powder before drying. The viscoid first of all suddenly fell below the temperature of the atmosphere. It fell much slower than the cotton fiber, and even at the end of 160 minutes' exposure it was still about 3° above the atmospheric temperature. At this point it had only recovered about 90 per cent. of its hygroscopic moisture, and it only came to a con-

stant weight after about 210 minutes' exposure. By grinding viscoid to a much finer powder than was used for the above, and repeating the experiments, a much more regular curve was obtained, and the hygroscopic moisture was very much diminished; but the time required for the material to fall to the temperature of the atmosphere was not lessened. I took some cotton wool which I ground to a fine powder, and I found that although it took about sixty minutes to recover its hygroscopic moisture, it contained only about 4 per cent. instead of 7 per cent. moisture. All these experiments were repeated with similar results. From this it is evident that the hygroscopic moisture of a cellulose, whether amorphous or in the fibrous condition, is dependent not only upon the character of the cellulose itself, but also upon the extent to which the cellulose is disintegrated. This is contrary to accepted views on the subject. It is only when particles of viscoid are below a certain size that the hygroscopic moisture is materially diminished. It appears that the cellulose that composes the cell walls of the ultimate fiber is under certain stress when deprived of moisture, in the same way that lumps of viscoid are when they are dried, and that the amount of stress determines the amount of moisture that it will take up to relieve the stress. Cellulose expands when hydrated, and it appears that the hygroscopic moisture is really water of hydration of the cellulose, and that it tends to hydrate in proportion to the stress that exists in the anhydrous cellulose. This accounts for the fact that the smaller particles of viscoid contain less hygroscopic moisture than the larger; also, which is more marked, disintegrated cotton fiber contains much less hygroscopic moisture than when the fiber is left intact. I have prepared small particles of viscoid, which, when bone-dry, would fly to pieces on being scratched, like "Prince Rupert Drops;" but the same particles, on being placed in a damp atmosphere, swell somewhat and recover their strength.

Particles can, on the other hand, be prepared in such a way that they do not exhibit brittleness, and they expand to a much less degree on being placed in a moist atmosphere. The results all tend to the same conclusion, in my mind, as to the nature of hygroscopic moisture in cellulose.

COMPRESSED AIR FOR CITY AND SUBURBAN TRACTION.*

BY HERMAN HAUPT.

Although a considerable amount of compressed air literature has been given to the public during the last two years, there is still a want of information as to the efficiency and economy of air motors as compared with cable, electric and other systems, and statements are continually published in the columns of the daily press that exhibit ignorance of scientific facts and apprehension of imaginary dangers.

Compressed air motors have been in successful operation in France for many years, and they are now rapidly establishing themselves in public favor in the United States. They have been constructed and tested at Rome, New York, continuously for two years, in all conditions of weather, and have given satisfaction even at temperatures below zero. Several motors are now, and have been, running for some months on the One-hundred-and-twenty-fifth Street Railway, in the city of New York, in daily service, without having lost a trip and with great satisfaction to the public.

The attention of the writer was first directed to the use of compressed air for city service in 1879, when he was called upon to examine, test and report upon several motors that had been constructed under the supervision of Robert Hardie, and allowed to be run on a portion of the Second Avenue Surface Railway, at Harlem, in New York. These motors were tested for several weeks, and the results were entirely satisfactory; but all attempts to secure their introduction proved fruitless. There was so strong a prejudice against them, that the president of one of the city railroads in Philadelphia declared that he would not have such a motor on his road if it saved the whole cost of horse-power; that it would frighten every team on the street to see a car

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* Read by title, November 18, 1896.

running without horses, and the company would be perpetually annoyed by lawsuits. Explanations proved useless, and efforts were abandoned.

After the far more objectionable and expensive cable and trolley systems had been introduced and had demonstrated that a car could be run without horses and without frightening teams, the writer renewed efforts to educate the public, and especially the profession, in regard to the superior merits of compressed air. A book was published, giving a description and comparative cost of all the systems known or used for city traction, based on similar conditions of service.

This was followed by a number of monographs on special points, and finally resulted in the formation of a syndicate to raise capital and organize a company under the title of the General Compressed Air Company. The services of Mr. Robert Hardie were secured as engineer, and a motor constructed at the Rome Locomotive Works, which proved entirely successful from the start, and has been examined, tested and favorably reported upon by engineers, experts and scientists from all parts of the United States without exception.

Very erroneous opinions have been and are yet entertained in regard to the power lost in compressing air, the frost produced in expansion, the danger of explosion, the reheating of dry and moist air, the cost of plant, the necessity for frequent renewals of air supply, the possible length of run, the loss by transmission of air to distant points, and other matters connected with the practical application of air as a motor-power.

That the subject of air motors may be intelligibly presented, it is necessary to state briefly some of the properties of air and the laws which govern its compression, expansion and distribution, also such of the properties of steam as enter into the consideration of the questions at issue.

PHYSICAL PROPERTIES OF AIR AND STEAM.

Air at a temperature of 32° F. requires 12·433 cubic feet to weigh 1 pound; at ordinary temperature about 13 feet.

The weight of steam at 212° is 26·4 cubic feet to the pound, or approximately, for rough calculation, 26 feet. *Specific heat*, or capacity for heat, varies with different substances, and it is a very important element in calculations in thermodynamics. Water, having the greatest capacity for heat, that is, having a capacity to retain the greatest number of heat units per pound, has been taken as the unit of specific heat. On this standard, the specific heat of air is ·2377, or approximately ·24.

The specific heat of steam is ·475, or approximately ·48, or double the specific heat of air. In other words, steam is half as heavy as air, but has double the capacity per pound for retaining heat.

If air be suddenly compressed to one-half its volume, the temperature will be raised 116°, and if suddenly expanded to double its volume the temperature will be reduced to the same extent.

Under high pressure a given increase of pressure will develop much less heat than at low pressure. For example, a given volume of air at atmospheric pressure, condensed suddenly to one-half by an increase of pressure of 15 pounds, would develop 116° of heat, while under a pressure of 25 atmospheres an increase of pressure of 1 atmosphere would raise the temperature only 16·7°.

A thermal unit, or unit of heat, is the quantity of heat that will raise the temperature of 1 pound of water 1°, and a thermal unit is the equivalent in work of 772 pounds raised 1 foot.

A horse-power is 33,000 pounds raised 1 foot in 1 minute.

Isothermal compression is compression without evolution of heat. If this were attainable in practice, as much energy could be utilized in the expansion of air as was expended in compression.

Adiabatic compression is compression with evolution of heat. By compression and intermediate cooling it is claimed that 80 per cent. efficiency may be obtained. Under old systems of compression the loss has been conceded to be 50 per cent. The capacity of air for holding moisture is affected by volume and temperature, but not by density. A

cubic foot of air will hold no more water at the same temperature under 133 atmospheres than under 1; consequently, when this air is expanded to original tension, 1 cubic foot will contain only $\frac{1}{133}$ part of the moisture that it had originally and should be too dry to form a deposit of ice at the exhaust even if not reheated. Only low pressures can contain sufficient vapor to cause trouble; but as air should always be reheated, for reasons that will be explained, the difficulty from frost is purely imaginary.

Absolute or theoretical zero is a point determined by theory 461° below the zero of Fahrenheit, from which temperature must be estimated in problems connected with expansion of elastic fluids, the volumes being in proportion to the temperatures from absolute zero. This datum will be found essential in considering the question of reheating.

Latent heat is the heat that disappears or becomes latent in change of form, as from a solid to a fluid, or from a fluid to a vapor, and which reappears by condensation when the original condition is resumed.

In the liquefaction of ice 142·5 units of heat per pound become latent, and in the conversion of water into steam 966 units; so that the latent heat of water-from ice is 142·5 units, and of steam 966°.

The specific heat of ice is ·50, so that the number of thermal units in 1 pound of steam at 212°, measured from absolute zero, will be $(461 + 32) \times \cdot 50 + 142 \cdot 5 + 180 + 966 = 1{,}535$ units.

An apology for these explanations and definitions seems to be required, as they apparently assume a want of information on the part of the reader, but there seems to be a necessity for explanations to remove the ignorance and prejudice that are almost universal. Even in technical journals, articles have appeared from the pens of gentlemen of high scientific reputation advocating the reheating of *dry* air to increase its power, and giving plans of apparatus for the accomplishment of this object. It will be shown that to double the power of dry air by an application of heat is practically impossible, and that it is only by an admixture of vapor that satisfactory results can be secured, yet this

demonstration could not be given without furnishing the data which it required.

AIR COMPRESSORS.

The use of compressed air for the operation of rock drills and for other purposes has become so extensive that it has led to great improvements in compressors, and several companies are now engaged in their manufacture who will furnish plants at moderate prices and guarantee results. Among these can be named the South Norwalk Iron Works Company, the Ingersoll Sargeant Drill Company and the Rand Drill Company. The best results are secured by repeated compressions with intermediate cooling, and large plants should always consist of a number of units, so that repairs to one will not affect the remainder, and the number in use at one time can be regulated by the demands of the traffic.

The experience gained by numerous tests, extending over a period of years, has furnished positive and reliable data by which to determine the amount of free air, under compression, required for any given service under any ordinary conditions. If responsible manufacturers of compressors will agree to furnish the plant at a given price, with a guarantee to compress a given number of cubic feet of free air per minute, delivered in station reservoirs under a given pressure, with a coal consumption and horse-power within prescribed limits, all elements of uncertainty as to cost of power seem to be removed; and this is being done.

The improvements in compressors have greatly increased their efficiency and extended the use of compressed air. In the primitive types an efficiency of 50 per cent. only could be secured; now 80 per cent. is claimed, while the ability to transmit power by this agency to long distances without serious loss, and to concentrate many small powers into a general reservoir will permit many water-powers to be utilized that would otherwise be worthless, and secure economies not offered by any other system.

The sudden compression of air is attended with a great evolution of heat. To compress two volumes of air into

one, as previously stated, will raise the temperature 116°; but it is a remarkable and valuable property of air and other elastic fluid, that under high pressures a given increase requires less power and develops less heat than under low pressures.

If, for example, it should be required to compress 3,600 cubic feet of free air per minute to a pressure of 500 pounds, the horse-power required would be 1,060 horse-power; if to 1,000 pounds the power would be 1,219 horse-power—a difference of 159 horse-power for 500 pounds; if to 1,500 pounds pressure, 1,288 horse-power, or a difference of 69 horse-power for 500 pounds; and if to 2,000 pounds, 1,339 horse-power, or a difference of only 51 horse-power to gain 500 pounds of additional pressure.

The power required to compress 1 cubic foot of free air is estimated as follows:

	Horse-power.
To 500 pounds pressure per minute	0·316
To 1,000 " " "	0·364
To 1,500 " " "	0·385
To 2,000 " " "	0·400

To which 10 per cent. allowance should be made in practice in allowing actual power for compressors.

Mr. E. Hill, the General Manager of the Norwalk Iron Works, gives absolute isothermal compression to 2,000 pounds per square inch per cubic foot of free air per minute, 0·315 horse-power, and the best possible in practice under the most favorable conditions, 0·378 horse-power. The computation of the writer gave 0·348 horse-power as the theoretical isothermal, but 0·45 should be allowed in practice. It is better to provide an excess of power than to suffer the inconvenience of a deficiency.

RE-HEATING.

A remarkable property of compressed air is that its efficiency can be doubled by re-heating. This is not theory; the fact has been confirmed by actual demonstration, both in Europe and America. It may appear incredible and contrary to well-known physical laws that the efficiency

of air can be doubled by simply passing it through a tank of hot water before admission to the motor cylinders, but such is the fact, and the reheating which doubles the power represents a consumption of coal only one-eighth of the amount required at the power station to produce the compression.

A direct test was made at Rome, on motor No. 100, in the presence of Capt. G. J. Fiebeger, of the U. S. Engineers, now Professor of Civil Engineering at West Point. The consumption of re-heated air from an average of many runs was 308 cubic feet per mile. When the re-heater was emptied of water, the volume of cold air required was 669 cubic feet per mile.

An explanation of this remarkable result will be given.

A comparison will be made between the results of reheating dry air to an extent sufficient to double its volume with and without the assistance of water, assuming the volume at 60° to be 300 cubic feet of free air, and that it is to be admitted to the motor cylinders under a pressure of 150 pounds to the square inch.

Assume, in the first place, that air at 60° is passed through a tank of water at 360°, giving a steam and air pressure of 150 pounds per square inch. The units of heat required to double the volume will now be determined.

The absolute temperature at 60° is $60 + 461 = 521°$.

The absolute temperature at 360° is $360 + 461 = 821°$, so that the air passing through water at 360° will be increased in volume, or under constant volume will be increased in pressure 63 per cent.

The thermal units required for the increase of temperature will be, 23 pounds of air raised 300°, specific heat of air being ·24. Then $23 \times 300 \times {\cdot}24 = 1{,}656$ units. The air has been increased in pressure 63 per cent., and to double the pressure by the addition of vapor or steam from the water will require the addition of 111 cubic feet of steam at atmospheric tension. That is, the 300 cubic feet of air at atmospheric tension has been increased to 489, and $489 + 111 = 600$. The 111 cubic feet of steam weighs 4·3 pounds, to secure which from water at 360° requires only the latent

heat, or 863 units. $863 \times 4 \cdot 3 = 3{,}711$, and adding the 1,656 units previously obtained, will give a total of 5,367 units.

Coal completely consumed will furnish 13,000 units per pound, petroleum 20,000 units per pound, and allowing for loss by imperfect combustion, 1 pound of coal or ½ pound of petroleum should furnish the fuel for re-heating at a cost of 2 mills for coal or 1¼ mills for crude petroleum, and 300 cubic feet of air thus re-heated should run an 8-ton motor much more than 1 mile.

To double the volume of air by the application of dry heat, the temperature must be double from absolute zero. At 60° observed temperature the absolute temperature would be $60 + 461 = 521°$, and the double would be 1,042°, and deducting 461° would leave the equivalent thermometric temperature 581°, a degree of heat that would burn out the lubricants and would be entirely inadmissible. In fact, it is stated in a recent work on compressed air by Mr. Frank Richards, that to double the power with dry air would require a temperature of about 800°, in consequence of the low specific heat of air and consequent rapid cooling.

As the air is supposed to be used expansively, so that the atmospheric tension is reached at the end of the piston stroke, the quantity of heat lost by expansion with an initial pressure of 10 atmospheres, or 150 pounds, would be 494°, which is nearly all that the heated air contained, so that if the admission could be at 581°, the exhaust would be 87°, without allowance for loss by radiation or conduction, and so much heat would be absorbed by the cylinder that the efficiency of the re-heated air would be greatly impaired.

On the other hand, if the air be passed through hot water, any vapor condensed in the cylinder yields its latent heat and steam, also acts as a lubricant.

Another striking comparison will be presented. Steam at 350° temperature and 150 pounds pressure, will, in cooling down to 212°, impart more than thirty times as much heat to the cylinders as an equal weight of air between the same temperatures.

The difference of temperature is 350 — 212 = 138°.
Specific heat of steam, ·475; air, ·24.

	Units.
1 pound of steam yields 138 × ·475	65·5
and of latent heat	966·0
Total heat from 1 pound of steam	1,031·5
1 pound of air reduced 138° yields 138 × ·24	33·12

One pound of steam carries as much heat as 31 pounds of air, and not only serves with little loss to maintain the cylinder and passages at a proper temperature, but, as previously stated, it also serves as a lubricant.

The reasonable conclusion is that it is practically impossible to heat dry air to an extent sufficient to double its power, and if practicable it would be inexpedient and the effect highly injurious.

The ideal re-heater would be a tank containing water at a temperature to furnish steam at the pressure of the air as used in the motor cylinders. The heat retained constant and uniform by cheap fuel, such as crude petroleum, and in winter the cars to be heated by water circulation from the same tank.

From tests made by him in 1879, the writer concluded that the average amount of water absorbed by the air and carried over in the form of steam was about 1 pound for 50 cubic feet of air. The accuracy of this result having been questioned, Mr. Hardie was requested to make a series of tests at Rome, the result of which established the fact that the quantity of water absorbed and carried over was dependent upon the temperature. At a high temperature in the water a comparatively small volume of air would suffice to evaporate a pound, and at a low temperature the volume of air was greatly increased.

The following table is interesting, showing the number of cubic feet of air at atmospheric tension required to absorb and carry over 1 pound of water in the form of steam or vapor:

Degrees F.	*Cubic Feet.*
At 321	35·2
At 300	42·5
At 296	43·3
At 274	48·5
At 259	95·2
At 210	159·0
At 190	238·0
At 182	229·0
At 170	221·0
At 164	459·0
At 158	493·0

RESERVOIRS.

The subject of reservoirs is one of the most important in connection with the construction of compressed air motors. The reservoir is the source of power in the motor, and upon its capacity and strength the possible length of run depends. Formerly, reservoirs were constructed of riveted boiler plates, and were capable of sustaining a pressure of from 300 to 600 pounds per square inch only. Consequently, a run of over 10 miles required so great an extension of capacity that room could be secured only by raising the floor to an inconvenient height above the rails. To secure long runs, with moderate reservoir capacity, high pressure is a necessity, and reservoirs are now manufactured, by a peculiar process, from solid ingots of mild steel, without a joint or weld, and which are capable of sustaining with safety a pressure of 2,000 pounds per square inch, the test, within the limits of elasticity, being carried to 4,000 pounds, leaving so large a factor of safety as to render rupture impossible.

It is proper to observe that the risk of rupture is not greater under a pressure of 2,000 pounds than it would be under 500 pounds, for the thickness of the shell would be four times as great with the higher pressure, and the strain per square inch of metal would be precisely the same in both cases.

Paradoxical as it may seem, it can be shown that a pressure of 2,000 pounds per square inch is actually more safe than a pressure of 500 pounds, notwithstanding the fact that newspaper scribblers, in the interest, apparently, of

rival systems, to create a prejudice against compressed air, magnify the risks of an explosion and the dangers to result therefrom.

Bear in mind that all reservoirs intended to carry 2,000 pounds are tested to 4,000 pounds, within elastic limits; consequently, the pressure could be increased 2,000 pounds more before the danger limit could be reached.

But if the pressure were 500 pounds the margin of safety would be the same, and the test would be to 1,000 pounds. Consequently, a variation of 500 pounds increase of pressure would reach the danger limit with the low-pressure reservoir, but would be 1,500 pounds below this limit with the high pressure. There can be no question of the sufficiency of the margin of safety.

But if, notwithstanding the theorizing upon the subject, the reservoirs should actually burst, would not the consequences be disastrous? The answer is no! A rent would be formed and the air would escape with a hissing noise. The material, unlike cast iron, is ductile and will stretch and pull apart and not fly in pieces.

The following extract from a letter from the manufacturers in Germany, addressed to the writer, will afford an explanation:

"Regarding the reservoirs, we put them to a test yesterday to state the elastic limit. It was reached at 3,500 pounds, but we went further in our experiments in order to demonstrate by practical test (as it has been demonstrated in hundreds of bursting tests of carbonic acid bottles) that these air bottles would not crack or fly to pieces, but that they would simply open when the breaking strain was reached (as was always the case with the carbonic acid bottles, when tested to bursting strain) and allow the contents to flow out, proving thereby that the handling of these bottles is in no way dangerous. We, therefore, think it advisable and safer for the future practical use of the bottles, not to test them, as we mutually agreed, till near to the bursting strain, but only till near to the elastic limits, because we are afraid that although they stand the test till near the bursting strain, the metal is somewhat weakened and, therefore, the practi-

cal use afterwards diminished. You will find the bottles somewhat lighter than ordered, and the question to decide for future deliveries will be whether you want the bottles as light as possible and use a storage pressure of 1,500 pounds per square inch, or if you prefer to make them somewhat heavier and use a storage pressure of 2,000 pounds per square inch. Please answer if you agree to the above, and we will send you the whole lot immediately. To-day we send you eight bottles, seven medium long and one short one, that you may, if you choose to do so, repeat the test to 3,500 pounds. As the fluctuations of the compressed air pressure, caused by the fluctuations in the atmospheric temperature are small when compared with the same fluctuations of the carbonic acid, we think it safe to test the air bottles only to the elastic limit, and use them with about half that pressure in practical work, as this way is safer than to test the bottles to the bursting strain and charge them only with one-third of that pressure afterwards in practical use."

Similar results have been indicated by tests in other localities, and it must be remembered that the rupture of a cylinder containing air produces effects that are widely different from those which result from the explosion of a steam boiler. When a boiler explodes, the volume of steam may be instantly increased more than a thousandfold by the conversion of water into steam by the reduction of pressure, the boiler is ruptured and pieces of iron and scalding water projected to great distances, while the rupture of an air cylinder allows a comparative moderate expansion of the contents, accompanied by a sensation of cold and not of heat.*

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* To illustrate more clearly the effect of the explosion of a steam boiler, let it be assumed that the dimensions of the boiler are 3 feet diameter and 12 feet long, containing 85 cubic feet, of which 70 cubic feet are water and 15 cubic feet of steam at a temperature of 350°.

The 70 cubic feet of water will weigh 4,375 pounds, and at 350° will contain 1,531,250 units of heat.

The 15 cubic feet of steam at 15 atmospheres will weigh 9 pounds and contain 10,602 units, and the whole contents of the boiler 1,541,870 units of heat.

Let $x =$ quantity of water at 212° not converted into steam by the explo-

WEIGHT OF RESERVOIRS.

The weight of reservoirs is in proportion to the number of cubic feet of free air that they inclose, and that again is in proportion to the length of run, and is entirely independent both of diameter and pressure.

The truth of this position can be demonstrated rigidly, but a simple explanation will suffice to make it clear.

Suppose a reservoir of any diameter, say 1 foot, is under a pressure of 2,000 pounds per square inch, 1 foot in length of such reservoir will weigh a certain number of pounds.

Now, suppose the diameter should be reduced to one-half or 6 inches, the thickness of metal to resist the pressure would be one-half as great as formerly, and the circumference also one-half, consequently the weight per foot would be one-fourth; but to secure equal capacity the cylinder must be four times as long, and, therefore, the weight, with a given capacity, must be the same whatever the diameter.

Again, suppose the pressure should be reduced from 2,000 to 1,000 pounds per square inch, the weight to resist this pressure would be reduced one-half, but to contain the same quantity of free air the capacity must be doubled, and, consequently, the weight would be the same as before.

It follows, therefore, that whatever may be the diameter of the reservoir or the pressure per square inch, the weight of reservoir to enclose a given *weight* of air will be constant.

What then is the weight per cubic foot of interior capacity required to resist a pressure of 2,000 pounds per square inch, equivalent to 136 cubic feet of free air?

If 35,000 pounds be assumed as the elastic limit of the material, and one-half, or 17,500 pounds, as the maximum

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sion. Then $4,375 - x =$ water converted into steam at 212°. Latent heat, 966 units. Then $212 + (4,375 - x)\ 966 + 10,602 = 1,541,870$. From which $x =$ 3,600 pounds, and $4,375 - 3,600 = 775$ pounds of water converted into steam by the explosion = 20,176 cubic feet, $20,176 + 225 = 20,401 =$ cubic feet of steam liberated, and $20,401 \div 15 = 1,360$ times the original volume of steam which has been increased by the explosion.

strain upon the metal per square inch from an interior pressure of 2,000 pounds, then it will be found that the weight per cubic foot of interior capacity will be 115 pounds. The weight of the last importation of the German reservoirs was 106 pounds per cubic foot of interior capacity.

As the 115 pounds per cubic foot under 2,000 pounds pressure contain 136 cubic feet of free air compressed into 1 foot, the required weight of reservoir will be 0·856 pound for each cubic foot of free air that may be enclosed.

If, in addition, it should be assumed that 400 cubic feet of free air should be provided to run an 8-ton motor 1 mile, with sufficient allowance for contingencies, the weight of reservoir per mile run would be 338 pounds. This weight, it must be understood, applies to the motor only, and is the equivalent of 42 pounds per ton of motor weight. Trail cars will require only about one-third as much per ton.

[*To be concluded.*]

RESULTS OF THE WORKING OF TWO-CYLINDER COMPOUND LOCOMOTIVES ON AMERICAN RAILWAYS.

By John H. Cooper.

I have the pleasure of presenting in detail the following results obtained during the year 1896, in regard to the working of compound locomotives.

These data relate exclusively to comparisons of performance between two-cylinder compounds and simple engines, when alike in every respect except the compounding devices, and working under similar conditions.

Two-cylinder compound locomotives may be treated under three heads or types, which may be defined in general terms as follows:

(1) Those in which the intercepting valve is automatic and which cannot be run as a simple engine. This type is without a reducing valve.

(2) Those in which the intercepting valve is operated by steam, but is under the control of the engine-driver, and is provided with a reducing valve, which is automatic.

(3) Those in which the intercepting valve is operated by a rod connection from the cab, under control of the engine-driver, either by hand or by steam or by air; this type also has a reducing valve, which is automatic, allowing the engine to be run either simple or compound, at will.

These types will be found fully illustrated and described in the technical journals.

Should it be desirable to obtain the results of the working of other types of compounds, in order that the comparison shall be of value to railway men, the data must come from persons running them with simple engines of like size and type, under exactly the same conditions as has been done in the case of the two-cylinder compounds.

The simple engine constitutes the standard of cost and running expenses, and is, therefore, the measure for ascertaining the commercial value of the several systems.

Were this comparison obtained, there would be little difficulty in determining the relative value of every type of compound, providing the performances of the simple engines exhibit such a similarity of result as will admit of easy and correct equating.

The writer and his colleagues, who have aided him in obtaining the facts here presented, have been particularly requested to withhold names of persons, roads and locomotives for reasons best known to the parties furnishing the data. Whether authorities are given or not, they offer truth for authority, upon which they rest our case.

They have been careful in getting these results of performance that they should be derived solely from the official records, which are made by persons whose duty it is to furnish the facts of experience.

With these preliminary explanations we present extracts of performance sheets of twelve compound engines, having cylinders 21 and 31 x 24; also of a simple engine, which is an exact duplicate of the compounds, except that the cylinders are single expansion. This engine carried the

same steam-pressure as the compound, and worked under precisely the same conditions. It will be noticed that these reports are for May and June, 1894, being the last ones received, and were furnished after the engines had been in use more than a year.

EXTRACTS FROM PERFORMANCE SHEETS FOR THE MONTH OF MAY, 1894.

	Consolidation Compound.	*Consolidation Simple.*
Number of miles run in freight service	16,520	2,425
Cost per mile for oil and waste (cents)	0·34	0·33
Cost per mile for fuel (cents)	13·52	16·66
Number of miles run to one pint of valve oil	53·02	86·61
Number of miles run to one pint of engine oil	21·34	14·97
Pounds of coal per loaded freight car, mile	3·41	4·46
Number of miles run to one ton of coal	21·49	17·43

YOUGHIOGHENY AND HOCKING COAL USED.

Cost of fuel-wood per cord	$1 86
Cost of fuel-coal per ton	2 87

MONTH OF JUNE, 1894.

	Consolidation Compound.	*Consolidation Simple.*
Number of miles run in freight service	13,478	1,827
Cost per mile for oil and waste (cents)	0·34	0·42
Cost per mile for fuel (cents)	11·68	18·09
Number of miles run to one pint of valve oil	63·07	39·72
Number of miles run to one pint of engine oil	17·81	14·50
Number of miles run to one ton of coal	25·08	16·13
Pounds of coal per loaded freight car, mile	3·43	4·30

YOUGHIOGHENY AND HOCKING COAL USED.

Cost of fuel-wood per cord	$1 86
Cost of fuel-coal per ton	2 87

From another source we make the following extracts:

"All conditions should be alike, save the compounding, and then the engines should be manned alike and have the same character of fuel, substantially the same loads, weather, etc. Further than this, the trial should be of sufficient length to carry it down to every-day work, and should cover the changing of engineers and firemen, as well as all the vicissitudes of weather and work. In no other way can we answer the criticisms or overcome the scepticism of many regarding the value of the compounding principle. We

must be able to show that we not only do save fuel, but that we do not have excessive repairs arising from the changes in machinery.

"It is of a trial of this character that I write, the compound engines being of the two-cylinder type. This paper is intended simply to show what these particular engines did, and not to demonstrate that other engines, or types, would or would not do just as well. The writer was able to cause this test from the fact that, in ordering a lot of engines, he had one ten-wheel passenger out of three, built on the same specifications, compounded, and two 'Consolidation' freight engines out of eighteen, on the same specifications, compounded. The weight of all these engines was the same, 126,000 pounds, without the tender, and they were delivered and put into service about the same time. The simple 'Consolidation' engines were 20 x 24-inch cylinders, while the compounds were 20⅝- and 29 x 24-inch. The cylinders of the ten-wheeled simple engines were 19 x 24 inches, while those of the compound were 19 and 27 x 24 inches. The 'Consolidations' were substantially duplicates of a large number of other engines of the same character, which, after some years' use, had been worked up to a very economical point. During the previous years, we had procured a ten-wheeled passenger engine, which had been changed, experimentally, until it had become unusually economical in fuel. This was the basis of the three new ten-wheeled engines, and they were found most excellent in their workings.

"The comparisons of the ten months' work of the passenger engines are shown in the following tables:

COMPARISON OF PASSENGER ENGINES.

	Miles Run.	Car-Miles.	Average Cars Per Train.	Pounds Coal Consumed.	Pounds Coal Per Car-Mile.
Two simple engines	107,885	564,995	5·23	6,263,654	11·086
One compound engine	48,100	254,204	5·17	2,097,911	8·252

"Saving, 2·834 pounds of coal per car-mile, or 25·56 per cent.

"The work of four simple and two compound freight engines for eleven months is shown, as follows:

SIMPLE ENGINES.

	Miles Run.	Car-Miles.	Average Cars Per Train.	Pounds Coal Consumed.	Pounds Coal Per Car-Mile.
Four engines, East End, 6 mos.	81,226	1,335,045	16·43	8,252,533	6·132
Four engines, West End, 5 mos.	61,318	1,190,786	19·41	5,977,917	5·029
Total, 11 mos.	142,544	2,525,831	17·23	14,230,450	5·634

COMPOUND ENGINES

	Miles Run.	Car-Miles.	Average Cars Per Train.	Pounds Coal Consumed.	Pounds Coal Per Car-Mile.
Two engines, East End, 6 mos.	27,682	495,050	17·88	2,454,142	4·957
Two engines, West End, 5 mos.	31,550	712,291	22·57	2,667,505	3·746
Total, 11 mos.	59,232	1,207,341	20·38	5,121,647	4·242

"Saving, 1·392 pounds of coal per car-mile, or 24·70 per cent.

"Here we have a marked saving in a year's work. We believe the conditions were such that the test is of more value than were the first ones made, as it shows the every-day work of the compound engines compared with exactly the same simple engine under the usual working conditions. No tests can be fairer, and I have seen none of more value.

"I regret to state it, yet it is true, that there was at the start a universal prejudice against the compounds among the engineers and firemen. They were pronounced failures before they were set up, and long after they had shown their good qualities the unfavorable criticism continued. They 'would not start the train,' but they did it. They 'could not run up the long hills,' but somehow they did it quite as easily as the other engines. They 'could not pull within two or three cars of the other engines,' but a year's work shows they averaged larger trains, and in repeated cases, they have pulled as heavy trains as any engines on the road.

"But when they saw the compound passenger engine run the round trip with a tender of coal, and run easily 100 miles with one tank of water, they had to admit that there was some good in the new departure.

"It is our belief that this test of nearly a year in everyday work, with changing engineers and firemen, against exactly similar simple engines, doing the same work at the same time, is more valuable than any tests yet reported in this country, and demonstrated beyond a question the value of the compound principle in locomotive engines, in the matter of coal consumption.

"The importance of this is seen when it is known that the cost of fuel is about 10 per cent. of the whole cost of operating, and when we consider that the 32,000 locomotives in this country probably consume 30,000,000 tons of coal per annum.

"There is, however, another matter to be considered, and it is one that has rendered American engineers sceptical as to the real value of the compound engine; that is, one of repairs, as well as first cost. It stands to reason that the cost of maintaining three cylinders or four cylinders will be larger than the cost of maintaining two.

"I have a report of the repairs upon the engines under consideration from January 1 to June 30, 1891, a period of six months, while they were running together, and for six months of the time in which the consumption of coal is considered.

"Considering first the freight service, we find that the

Four simple engines in six months ran	76,827 miles.
Total cost of running repairs done	$1,312.66
Cost per mile run (cents)	1·70

"In the same time and over the same ground, the

Two compound engines ran	39,268 miles.
And the running repairs cost	$612.72
Or per mile (cents)	1·55

"Showing that for six months the compound ran more economically than the simple, as far as repairs are concerned. It is quite probable, however, that in another six

months this would be evened up, and the cost per mile would have likely been equal to that of the simple engines.

"When we consider that with cheap coal (say $1.50 per ton) the cost per engine mile for fuel is, for freight trains, about 7 cents per mile, and for passenger 4½ cents, we can see that a saving of even 20 per cent. in fuel means over 1 cent a mile, and that it cannot be outweighted by any reasonable, or I may say possible, increase of repairs, as but a small part of such repairs pertain to, or are affected by, the parts compounded.

"We believe this to have been a good practical test of the two-cylinder type of compound engines, and while no claim is made to perfection, it seems to have covered a sufficient length of time, amount of work and variety of climatic and other conditions, to have overcome the influence of any prejudices, or efforts for or against any particular engine or of any special skill on the part of any one man, that in a short run or experiment might have a marked effect."

From another source we quote:

"Where coal costs from $3.50 to $4 per ton, of course economy in the quantity consumed is a matter that is looked after.

"One of these two-cylinder locomotives has been running for about three years past, and the reports we have received from the officials of the railway company go to show that the saving in fuel, due to the compound system, has averaged about 17 per cent. comparing it with simple engines of the same type and capacity, doing practically the same work, and run on the same division.

"The saving of fuel in the case of the other four compounds on the same line which have been in service for about one year past, is said to be about the same—17 per cent.—as compared with the simple engines. No special tests or efforts have been made, so far as we know, in the matter of saving fuel; but the results are obtained from the monthly reports of fuel consumed by the locomotives on the line.

"The reports as to the cost of repairs of these compounds

indicate that they are little, if any, more than the simple engines, doing the same work on the same line.

"In the case of the other four compound locomotives, sent to another road, we have as yet received but little data as to their consumption of fuel. Some tests that were made, but continued for about ten days only, showed results that indicate a saving of about 20 per cent.

"We think that on an average, 'taking things as they come,' the saving will result about the same as in the other case, namely, 17 per cent."

From another source:

"Four compounds are reported, one of them running two years, one ten months; in all running 117,945 miles in freight service, and 2,946 miles in passenger service. Also, five simple engines, making 1,063,975 engine-miles in freight service, and 3,324 miles in passenger service.

"The chief results are in favor of the compounds, and are as follows:

	Per Cent.
Engine-miles per ton of coal	25·36
Pounds of coal per 100 ton-mile	23·59
" " " " engine-mile	19·00
" " " " car-mile	24·17
" " water per 100 ton-mile	28·85
" " " " engine-mile	16·84
" " " " car-mile	18·91

"We have reports as follows:

	Simple.	*Compound.*
On one road, repairs per train-mile (cents)	2·1	1·5
On another road, repairs per train-mile (cents)	4·11	3·90
" " " " " " " (cents)	3·13	2·88

"These are all the data we have on repairs; and it will be noticed that the compound beats the simple by about 13 per cent.

"The data on lubrication shows that on one road the compound used 12 per cent. more oil than the simple, and on another road 17 per cent. less."

From another source:

"Without giving you the results of any experiments or tests, I should say, in a general way, that a compound loco-

motive, when new, will save about 25 per cent. in fuel over a simple engine.

"I am convinced from our experience here that the compound engine in passenger service is of great value for fast trains, because a run of a hundred miles can be made with one tank of water, thus avoiding any stops, except at division terminals. The use of such engines avoids the necessity for building track tanks, and of course is a great saving. In addition to this, the engines run very much cleaner and make but little smoke when properly handled."

From another source:

"In compliance with my promise to advise you of the performance of your two-cylinder compound engines, I will state that their work is in every respect superb.

"We have had an engine in our express freight service, in competition with two 'Moguls' (simple engines) with 19 x 24-inch cylinders, carrying 160 pounds working steam pressure. These engines are all rated the same, *i. e.*, they are all given trains of 700 tons each. The consumption of coal is as follows: Compound engine ran in April, 1895, 31·1 miles per ton of coal, while the two 'Moguls' averaged 16·2 miles per ton."

From another source:

"These engines are designed to carry 200 pounds steam pressure. They are as nearly alike as possible, although they vary somewhat in their weight.

"The total weight of the compound is 127,500 pounds, and of the simple engine 117,460 pounds. Average steam pressure on test, 150 pounds. Average amount of coal burnt each trip—the compound, 6,150 pounds; the simple, 6,414 pounds. Average coal per car-mile in pounds—the compound, 6·72; the simple, 7·55. Average pounds of water evaporated per pound of coal—compound, 7·86; simple, 6·67. Relative amounts of coal burned on basis of car-mile —the compound, 100 per cent.; the simple, 112·35 per cent.

"The cost of the maintenance of these locomotives in a test occupying so short a time plays no part. The engines, prior to the test, were put in first-class condition, practically as good as new, and the repairs amounted to nothing."

From another source:

"We have in service three two-cylinder compound engines. They have been in service since November, 1894, and we are very well pleased with the general results given by them. They show from 30 to 33 per cent. saving in fuel; about 25 per cent. in evaporation. While there is no claim made for saving in repairs, we find that the cost of repairs is only a fraction of a cent more than the simple engine. The engines are virtually simple engines, having but two cylinders and no complication of parts over simple engines, with the exception of one intercepting valve and one reducing valve.

"Those comparisons were made with simple engines running in the same service and under the same conditions."

From another source:

"We have in service two ten-wheel compound engines of the two-cylinder type and a large number of ten-wheel simple engines, which, with the exception of the compound feature, are duplicates of the two compound engines. These engines have been used in freight service entirely, with the exception of a very small amount of passenger service, and I take pleasure in submitting below a comparative statement of the performance of the engines mentioned during the past five years:"

	Simple.	*Compound.*
Cost per mile for oil and waste (cents)	0·18	0·21
" " " " repairs (cents)	2·49	3·69
Miles run per ton of coal	20·51	22·58
Pounds coal consumed per car-mile	3·10	3·00
Total cost per car per mile (cents)	0·56	0·68

From another source:

"I will give you the figures as returned to me by our Comptroller, of the performance of these engines in regard to fuel.

"In the month of May, 1895, a compound engine, in passenger service, made a mileage of 5,558; her average number of miles per ton of coal was 49·5. Simple engine, in the same service, running opposite to the compound, made a mileage of 4,843, and her average mileage per ton of coal

was 41. These two engines were on night runs, consisting of seven-car trains, postal and baggage cars, two coaches and three sleepers, all vestibule.

"We have had the passenger engine for about eighteen months, and she has given entire satisfaction; is very economical on repairs and especially so on fuel.

"In our freight service we have a two-cylinder compound engine, which, in the month of May, on our fast freight schedule, made 3,003 miles—average miles per ton of coal, 33. Our simple engines running in the same service made a mileage of 2,860—average number of miles per ton of coal, 19·2. Same weight of train.

"The distance from terminal to terminal is 143 miles. The simple engines are limited to 7½ tons of coal per trip, and the compound freight engine was limited to 5 tons of coal per trip.

"I have had no complaint from the engineer running the compound engine of being short of fuel, but I had several complaints from the men running the simple engines where they were short of fuel. The compound engines, both passenger and freight, show a remarkable saving of fuel, and we are highly pleased with their performance."

From another source:

"To say the least, we are very highly pleased with the two-cylinder compound engines. The legitimate cost of repairs is no greater than on the simple engines.

"In the use of cylinder oil they are making about double the mileage of the simple engines, and, on fuel, they are saving at least 25 per cent."

From another source:

"I am pleased to record the fact that we have nineteen of your engines in our service from two to three years, and they have given most excellent satisfaction, both in character of workmanship and effective working and maintenance.

"It is a special pleasure to record the advantages afforded by your type of compound engine, evinced by their economy of fuel and moderate repairs."

THE STANDARD OF EFFICIENCY FOR STEAM-ENGINES AND OTHER HEAT-MOTORS.

BY R. H. THURSTON.

[*Concluded from vol. cxlii, p. 458.*]

The Method of Computation of the efficiency of the cycle for dry and saturated steam is as follows:*

Rankine's Jacketed Engine Cycle.

v_1 = volume in cubic feet at point of cut-off.
= initial volume = volume of 1 pound dry and saturated steam at the pressure chosen.
[Take this from steam-tables.]

v_2 volume at end of expansion.
$= v_1 r$.

r = ratio of expansion.

p_1 = initial pressure in pounds per square foot, absolute.

p_2 = pressure at end of expansion expressed in pounds per square foot, absolute.
[From steam-tables.]

p_3 = back pressure in pounds per square foot, absolute.

J = 778 foot-pounds.

a = 1,117,850 foot-pounds.

b = 544·5 foot-pounds.

T_1 = absolute temperature in degrees F., corresponding to p_1.
[Take temperature from steam-tables, and add 461°.]

T_2 = absolute temperature in degrees F., corresponding to p_2.

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* "Manual of the Steam Engine," Vol. I, § 118.

T_4 = absolute temperature in degrees F. of feed-water.

H_1 = heat per pound of steam (at boiler) in foot-pounds.

$= J(\lambda_1 - q_4)$.

H' = heat expended per pound of working steam, in foot-pounds.

= H_1 plus the heat received by the working steam from the jacket.

$$= J(T_2 - T_4) + a\left(1 + \log_e \frac{T_1}{T_2}\right) - b\,T_1.$$

Enter this in place of H_1 in the table.

"Working steam" is the steam passed through the cylinder.

U = net work done, in foot-pounds, per pound of working steam.

$$= a \log_e \frac{T_1}{T_2} - b(T_1 - T_2) + v_2(p_2 - p_3).$$

$$\text{Efficiency} = \frac{U}{H'_1}.$$

$$\text{M.E.P.}' = \frac{U}{r\,v_1} = \frac{U}{v_2} \text{ in pounds per square foot.}$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} \text{ in pounds per square inch.}$$

A = B.T.U. per I.H.P. per hour $= \dfrac{2545}{\text{Efficiency}}$.

B = pounds of steam per I.H.P. per hour at boiler (inclusive of jacket-steam) for efficiency unity.

$$= \frac{1980000}{H_1} = \frac{1980000}{J(\lambda - q_4)}.$$

B' = pounds of working steam per I.H.P. per hour for efficiency unit.

$$= \frac{1980000}{H'_1}.$$

C = pounds of steam per I.H.P. per hour, total (jacket and working charge) for actual efficiency.

$$= \frac{B}{\text{Efficiency}}.$$

C' = pounds of working steam per I.H.P. per hour for actual efficiency.

$$= \frac{B'}{\text{Efficiency}}.$$

W = equivalent water-rate from and at 212° F.

$$= \frac{A}{966069}.$$

F = pounds fuel per I.H.P. per hour.

$$= \frac{A}{10000}.$$

D = piston displacement per I.H.P. per hour.

$= C' v_2$ cubic feet.

D' = piston displacement per I.H.P. per minute.

$$= \frac{D}{60}.$$

Illustrative Examples follow, in which the maximum steam-pressure is assumed to be exceptionally high, 400 to 500 pounds per square inch, absolute, the terminal pressures to be identical with the back-pressures in the case of the Carnot cycle, and to be usually 7 pounds per square inch in the condensing and 21 pounds in the non-condensing engine; while the back-pressures are taken at 2 and at 16 pounds, respectively, for the condensing and the non-condensing engines and for their Carnot representatives.

The methods which have been outlined are followed in these cases, and the results of computation by various computers give an excellent series of data for comparison, bringing out well the relative efficiencies of the several cycles as well as their absolute efficiencies, and serving also to exhibit, in an instructive manner, when compared with the real engine cycle, the extent and the character of the physical defects of the actual engine.

In these cases, it is assumed that the quality of the fuel and the efficiency of the boiler are such as to permit the evaporation of 10 pounds of the feed-water supplied, per

pound of fuel, in the case of the non-condensing engine—which is supposed to employ a heater capable of raising the temperature of the feed-water to 200° F.—of 9 pounds in the case of the condensing engine, taking the feed-water from its hot-well, and 12 pounds in the Carnot engine, the "feed-water" being, in this case, at the temperature of the prime steam, and only demanding its heat of vaporization to transform it into steam of boiler-pressure.

CASE I. THE CARNOT CYCLE.

(*a*) In this case the data and results are as follows:

(*a*) "*Non-condensing*" *Type.*

$p_1 = 400 \times 144 = 57{,}600$ pounds per square foot.
$V_1 = 1 \cdot 167$ cubic feet.
$T_1 = 905 \cdot 92°$ F., absolute.

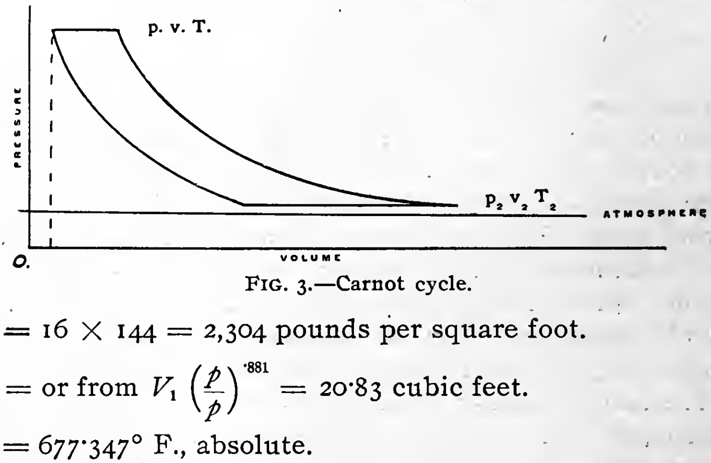

FIG. 3.—Carnot cycle.

$p_2 = 16 \times 144 = 2{,}304$ pounds per square foot.

$V_2 =$ or from $V_1 \left(\frac{p}{p}\right)^{\cdot 881} = 20 \cdot 83$ cubic feet.

$T_2 = 677 \cdot 347°$ F., absolute.

$log. p_1 = 4 \cdot 760422$ $log. \left(\frac{p_1}{p_2}\right)^{\cdot 881} = 1 \cdot 251585.$

$log. p_2 = 3 \cdot 362482$ $log.\ v_1 = \cdot 067071.$

$log. \frac{p_1}{p_2} = 1 \cdot 397940$ $log.\ V_2 = 1 \cdot 318656$ $V_2 = 20 \cdot 83.$

$L_1 = 797 \cdot 94$ B.T.U.

$H_1 =$ heat expended per pound of steam in foot-pounds.
$= J\ L_1 = 797 \cdot 95 \times 778 = 620797.$

r, ratio of expansion $= \dfrac{v_2}{v_1} = \dfrac{20{\cdot}83}{1{\cdot}167} = 17{\cdot}85.$

J = 778 feet per heat unit.

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1} = \frac{905{\cdot}92 - 677{\cdot}347}{905{\cdot}92} = 25{\cdot}3 \text{ per cent.}$$

U = net work per pound of steam expresssed in foot-pounds.

$= H_1 \times \text{Efficiency} = 620797 \times 0{\cdot}253 = 157{,}062$ foot-pounds.

$$\text{M.E.P.}' = \frac{u}{v_2} \text{ in pounds per square foot} = 7{,}540.$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} = 52{\cdot}4 \text{ pounds per square inch.}$$

$$A = \text{B.T.U. per horse-power per hour } \frac{\dfrac{33000 \times 60}{778}}{\text{Efficiency}} = \frac{2545}{\text{Efficiency}}.$$

$$= \frac{2545}{0{\cdot}253} = 10059.$$

This value of A is, however, for an efficiency of boiler of unity; but, according to the assumptions of the problem, the boiler efficiency was such as to evaporate 12 pounds of water per pound of coal of 10,000 B.T.U. If the efficiency were unity, the number of pounds evaporated would be:

$$\frac{10000}{797{\cdot}94} = 13{\cdot}79 \text{ pounds.}$$

Then A_1 = B.T.U. supplied to boiler will equal

$\dfrac{A}{\text{Efficiency of boiler}}$. Efficiency of boiler $= \dfrac{12}{13{\cdot}79} = 87{\cdot}01$ per cent.

$$A_1 = \frac{A}{{\cdot}8781} = \frac{10059}{{\cdot}8701} = 11558 \text{ B.T.U. per horse-power.}$$

B = pounds of steam pèr horse-power per hour for efficiency unity $= \dfrac{1980000}{H_1} = \dfrac{1980000}{620797} = 3{\cdot}19$ pounds.

C = pounds of steam per horse-power per hour for actual efficiency $= \frac{B}{\cdot 253} = 12\cdot 6$ pounds.

W = equivalent water-rate from and at 212° F. $= \frac{A}{966\cdot 069} = \frac{10059}{966\cdot 069} = 10\cdot 41$ pounds.

T = pounds of fuel per horse-power for efficiency unity $= \frac{A}{10000} = \frac{10059}{10000} = 1\cdot 0059$ pounds.

F_1 = pounds of fuel per horse-power per hour for efficiency of boiler of 87·01 per cent. $= \frac{F}{\cdot 8701} = \frac{1\cdot 0059}{\cdot 8701} = 1\cdot 15$ pounds.

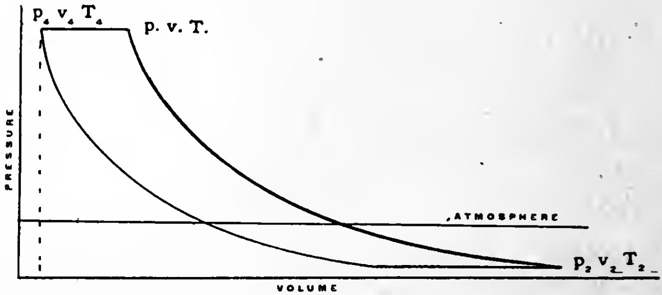

FIG. 4.—Carnot cycle.

D = piston displacement per horse-power per hour $= C v_2$ cubic feet $= 12\cdot 6 \times 20\cdot 83 = 262\cdot 46$.

D_1 = piston displacement per horse-power per minute $= \frac{D}{60} = \frac{262\cdot 46}{60} = 4\cdot 347$ cubic feet.

(*b*) "*Condensing*" *Type.*

$p_1 = 400 \times 144 = 57,600$ pounds per square foot.
$V_1 = 1\cdot 167$ cubic feet.
$T_1 = 905\cdot 92°$ F., absolute.
$p_2 = 2 \times 144 = 288$ pounds per square foot.
$V_2 = V\left(\frac{p_1}{p_2}\right)^{\cdot 881} = 106\cdot 45$.
$T_2 = 587\cdot 302°$ F., absolute.

$L_1 = 797{\cdot}94$ B.T.U.

r = ratio of expansion $= \frac{v_2}{v_1} = \frac{106{\cdot}45}{1{\cdot}167} = 91{\cdot}23$.

J = 778 foot-pounds per heat unit.

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1} = \frac{905{\cdot}92 - 587{\cdot}302}{905{\cdot}92} = 35{\cdot}17 \text{ per cent.}$$

$H_1 = J\,L_1 = 620797$.

$U = H_1 \times \text{Efficiency} = 620797 \times {\cdot}3517 = 218332$.

$\text{M.E.P.}' = \frac{u}{v_2}$ in pounds per square foot $= 2050{\cdot}1$.

$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} = 14{\cdot}2$ pounds per square inch.

A = B.T.U. per horse-power per hour $= \frac{2545}{\text{Efficiency}}$

$= \frac{2545}{{\cdot}3517} = m\,7236$ B.T.U.

$A_1 = \frac{A}{\text{Efficiency of boiler}}$. Efficiency of boiler $= 87{\cdot}01$

$= \frac{7236}{{\cdot}8701} = 8317$.

$$B = \frac{1980000}{H_1} = \frac{1980000}{620797} = 3{\cdot}19.$$

$$C = \frac{B}{\text{Efficiency}} = \frac{B}{{\cdot}3517} = \frac{3{\cdot}19}{{\cdot}3517} = 9{\cdot}07.$$

$$W = \frac{A}{966{\cdot}069} = 7{\cdot}49 \text{ pounds.}$$

$F = \frac{A}{10000}$ = pounds fuel per horse-power per hour for efficiency unity of boiler, and taking 10000 as the B.T.U. in pounds coal—

$= \frac{7236}{1000} = {\cdot}7236$ pounds.

F_1 = pounds coal for actual efficiency of boiler.

$= \frac{F}{{\cdot}87} = {\cdot}837$ pounds coal per horse-power per hour.

D = piston displacement per horse-power per hour.
$= c\, v_2$ cubic feet $= 9 \cdot 07 \times 106 \cdot 45 = 976 \cdot 15$.

D_1 = piston displacement per horse-power per minute.

$$= \frac{D}{60} = 16 \cdot 27 \text{ cubic feet.}$$

CASE II. RANKINE CYCLE. NON-CONDUCTING CYLINDER.

(a) Condensing Type.

$p_1 = 400 \times 144 = 57600$ pounds per square foot.
$V_1 = 1 \cdot 167$ cubic feet.
$T_1 = 905 \cdot 92°$ F., absolute.
$p_2 = 7 \times 144 = 1008$ pounds per square foot.
$T_2 = 639 \cdot 945°$ F., absolute.

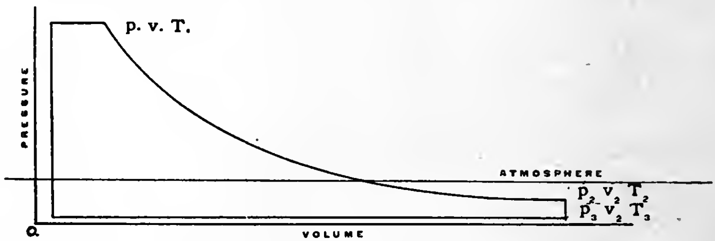

FIG. 5.—Rankine cycle. Non-conducting cylinder.

$$V_2 = v_1 \left(\frac{p_1}{p_2}\right)^{\frac{1}{1 \cdot 135}} = v_1 \left(\frac{p_1}{p_2}\right)^{\cdot 881} = 41 \cdot 205.$$

$$r = \frac{v_1}{v_2} = \left(\frac{p_1}{p_2}\right)^{\cdot 881} = 35 \cdot 3.$$

$p_3 = 2 \times 144 = 288$ pounds per square foot.
$J = 778$ foot-pounds per heat unit.
$log.\ p_1 = 4 \cdot 760422.$

$$log.\ p_2 = \frac{3 \cdot 003461}{1 \cdot 756961}.$$

$$log.\ \left(\frac{p_1}{p_2}\right)^{\cdot 881} = 1 \cdot 547883.$$

$log.\ v_1 = \cdot 067071.$
$log.\ v_2 = 1 \cdot 614954.$
$T_3 = 587 \cdot 302°$ F., absolute.

$T_4 = 120 + 461 = 581°$ F., absolute.

λ_1 = total heat of evaporation above 32° in B.T.U. at p = 1217·7.

q_4 = heat in feed-water above 32° at T_4 in B.T.U.
$= 581° - (461 + 32) = 581 - 493 = 88$ B.T.U.

U = net work of a pound of steam in foot-pounds for efficiency of engine.

$$= J_1 \left[T_1 - T_2 \left(1 + log_e \frac{T_1}{T_2}\right)\right] + \left(\frac{T_1 - T_2}{T_1}\right) H' + v_2(p_2 - p_3)$$

$$= 778\,[905{\cdot}92 - 639{\cdot}945\,(1{\cdot}3365)] + \frac{265{\cdot}975}{905{\cdot}92} H' +$$

$41{\cdot}205 \times 720 = 250470$ foot-pounds.

L_1 = latent heat evaporation at p in B.T.U. = 797·94.

H' = latent heat evaporation at p in foot-pounds = $J\,L_1$ = 620997.

H_1 = heat expended per pound of steam in foot-pounds.
$= J\,(\lambda - q_4) = 778\,(1217{\cdot}7 - 88) = 878806{\cdot}6.$

$$\text{Efficiency} = \frac{u}{H_1} = \frac{250470}{878806} = 28{\cdot}5 \text{ per cent.}$$

$$\text{M.E.P.}' = \frac{u}{r\,v_1} = \frac{u}{v_2} = \text{in pounds per square foot} = 6979.$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} = 42{\cdot}215 \text{ pounds per square inch.}$$

B = pounds steam per horse-power per hour for efficiency unity $= \dfrac{1980000}{H_1} = 2{\cdot}36$ pounds.

A = B.T.U. per horse-power per hour.

$$= \frac{2545}{\text{Efficiency}} = \frac{2545}{{\cdot}285} = 8930.$$

C = pounds of steam per horse-power per hour for actual efficiency $= \dfrac{B}{\text{Efficiency}} = \dfrac{2{\cdot}36}{{\cdot}285} = 8{\cdot}28.$

W = equivalent water-rate from and at 212° F.

$$= \frac{A}{966{\cdot}069} = 9{\cdot}24 \text{ pounds.}$$

F = fuel per horse-power per hour for boiler efficiency unity

$$= \frac{A}{10000} = \cdot 8930.$$

F' = actual fuel per horse-power per hour for evaporation, 9 pounds water per pound coal.

$$= \frac{C}{9} = \frac{8\cdot 28}{9} = \cdot 92 \text{ pounds coal per horse-power per hour.}$$

D = piston displacement per horse-power per hour.

$= C\,V_2$ cubic feet $= 8\cdot 28 \times 41\cdot 205 = 241\cdot 18$ cubic feet.

D' = piston displacement per horse-power per minute.

$$= \frac{D'}{60} = \frac{341\cdot 18}{60} = 5\cdot 68 \text{ cubic feet per minute.}$$

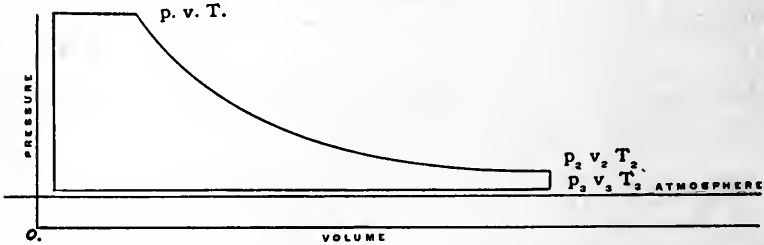

FIG. 6.—Rankine cycle. Non-conducting cylinder.

(b) Non-condensing Type.

$p_1 = 400 \times 144 = 57600$ pounds per square foot.

$T_1 = 905\cdot 92°$ F., absolute.

$V_1 = 1\cdot 167.$

$p_2 = 21 \times 144 = 3024$ pounds per square foot.

$$V_2 = V_1 \left(\frac{p_1}{p_2}\right)^{\cdot 881}$$

$log.\ p_1 = 4\cdot 760422 \qquad log.\ \left(\frac{p_1}{p_2}\right)^{\cdot 881} = 1\cdot 138539$

$log.\ p_2 = 3\cdot 480582 \qquad log.\ v_1 = \cdot 067071$

$log.\ \frac{p_1}{p_2} = 1\cdot 279840 \qquad log.\ v_2 = 1\cdot 205610$

$V_2 = 16\cdot 06.$

$T_2 = 230\cdot 565 - 461 = 691\cdot 565°$ F., absolute.

$$r = \frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{\cdot 881} = 13\cdot 7.$$

J = 778 foot-pounds per heat-unit.
T_3 = temperature F. degrees, absolute, of $p_3 = 677{\cdot}347$.
T_4 = absolute temperature F. feed-water = 461 + 200 = 661°.
λ_1 = total heat of evaporation at $p_1 = 6771217{\cdot}7$ B.T.U.
q_4 = heat in feed-water per pound above 32° in B.T.U.
$= T_4 - (461 + 32) = 661 - 493 = 168.$
$p_3 = 144 \times 16 = 2304.$
L_1 = latent heat of evaporation at p_1 in B.T.U. = 797·94.
H' = latent heat of evaporation at p in foot-pounds $= J\,L_1$ = 62797.
U = net work of a pound of steam in foot-pounds for the efficiency of the engine.

$$= J\left[T_1 - T_2\left(1 + log._e \frac{T_1}{T_2}\right)\right] + \left(\frac{T_1 - T_2}{T_1}\right)H' - V_2\ (p_2 - P_3).$$

$$\frac{T_1}{T_2} = \frac{905{\cdot}92}{691{\cdot}565} = 1{\cdot}31 \qquad log._e \frac{T_1}{T_2} = {\cdot}27.$$

$$\frac{T_1 - T_2}{T_1} = \frac{214{\cdot}36}{905{\cdot}92} = {\cdot}2366.$$

$$U = 778\,[905{\cdot}92 - 691{\cdot}565\,(1{\cdot}27)] + ({\cdot}2366 \times 620797) - 16{\cdot}06 \times 720.$$
$$= 21493{\cdot}92 + 146880{\cdot}5 + 11563{\cdot}2.$$
$$= 169937{\cdot}6.$$

H_1 = heat expended per pound of steam, in foot-pounds.
$= J\,(\lambda_1 - q_4) = 778\,(1217{\cdot}7 - 168) = 816666{\cdot}6$ foot-pounds.

$$\text{Efficiency} = \frac{U}{H_1} = \frac{169937{\cdot}6}{816666{\cdot}6} = 20{\cdot}82 \text{ per cent.}$$

$$\text{M.E.P.}' = \frac{U}{r\,v_1} = \frac{U}{v_2} \text{ pound per square foot} = \frac{169937{\cdot}6}{1606} = 10581.$$

M.E.P.″ = mean effective pressure in pounds per square inch $= \dfrac{\text{M.E.P.}'}{144} = 73{\cdot}48.$

A = B.T.U. per horse-power per hour.

$$= \frac{2545}{\text{Efficiency}} = \frac{2545}{{\cdot}2082} = 12235.$$

B = pounds steam per horse-power per hour for efficiency unity $= \frac{1980000}{H_1} = \frac{1980000}{816666 \cdot 6} = 2 \cdot 42$ pounds.

C = pounds steam per horse-power per hour actual efficiency engine $= \frac{B}{\text{Efficiency}} = \frac{2 \cdot 42}{\cdot 2082} = 11 \cdot 68$ pounds.

F' = pounds coal actual per horse-power per hour for efficiency of boiler such as to evaporate 10 pounds water from temperature 200° to steam at 400 pounds per square inch.

$$= \frac{C}{10} = \frac{11 \cdot 68}{10} = 1 \cdot 168 \text{ pounds coal.}$$

W = equivalent water-rate from and at 212° F.

$$= \frac{A}{966 \cdot 069} = \frac{12235}{966 \cdot 069} = 13 \cdot 66.$$

D = piston displacement per horse-power per hour.
$= C\,V$ cubic feet — $11 \cdot 68 \times 16 \cdot 06 = 187 \cdot 58$ cubic feet.

D' = piston displacement per horse-power per minute.

$$= \frac{D}{60} = \frac{187 \cdot 58}{60} = 3 \cdot 126 \text{ cubic feet.}$$

CASE II. RANKINE'S JACKETED CYCLE.

(a) Condensing Type.

$p_1 = 400 \times 144 = 57600$ pounds per square foot, absolute.
$V_1 = 1 \cdot 167$ cubic feet volume at cut-off of 1 pound at p_1.
$T_1 = 905 \cdot 92° =$ F. absolute temperature at cut-off.
$p_2 = 7 \times 144 = 1008$ pounds per square foot, absolute.
$T_2 = 639 \cdot 945°$ F., absolute, of steam at p_2.
$v_2 = 52 \cdot 89$ cubic feet volume of saturated steam at pressure p_2.
$p_3 = 2 \times 144 = 288$ pounds per square foot, absolute = back pressure.
$T_4 = 120 + 461 = 581°$ absolute F. temperature of feed-water.
$J = 778$ foot-pounds per heat unit.
$a = 1 \cdot 117850$ foot-pounds, a constant.

b = 544·5 foot-pounds, a constant.
H_1 = heat per pound of steam at boiler in foot-pounds.
$= J(\lambda_1 - q_4) = 878806{\cdot}6$ foot-pounds.
λ_1 = total heat of evaporation above 32° per pound steam at p.
= 1217·7 B.T.U.
q_4 = heat in feed-water above 32° F.
$= T_4 - (493) = 581 - 493 = 88$ B.T.U.
H_1' = heat expended per pound working steam in foot-pounds.
= H_1 plus heat received from the jacket.

$$= J\,(T_2 - T_4) + a\left(1 - log._e \frac{T_1}{T_2}\right) - b\,T_1.$$

FIG. 7.—Rankine cycle. Jacketed cylinder.

$= J\,(T_2 - T_4) + a\,(1{\cdot}3365) - b\,T_1.$
$= 778\,(58{\cdot}945) + 1{\cdot}117850 \times 1{\cdot}3365 - 544{\cdot}5 \times 905{\cdot}92.$
$= 45863{\cdot}1 + 1494006{\cdot}5 - 493273{\cdot}4.$
= 1046596 foot-pounds.

U = net work done in foot-pounds per pound "working steam."

$$= a\,log._e \frac{T_1}{T_2} - b\,(T_1 - T_2) + v_2\,(p_2 - p_3).$$

$= 1117850 \times {\cdot}3365 - 544{\cdot}5 \times 265{\cdot}965 + 52{\cdot}89 \times 720.$
$= 376156{\cdot}5 - 146817{\cdot}2 + 38080{\cdot}8.$
= 267420·1 foot-pounds.

$$\text{Efficiency} = \frac{U}{H_1'} = \frac{267420{\cdot}1}{1046596{\cdot}2} = 25{\cdot}55 \text{ per cent.}$$

$$\text{M.E.P.}' = \frac{U}{r\,v_1} = \frac{U}{v_2} \text{ in pounds per square foot} = 5056{\cdot}16.$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P}'}{144} \text{ in pounds per square inch} = 35{\cdot}11$$

pounds.

B = pounds of steam per horse-power per hour at boiler, inclusive of jacket-steam, for efficiency unity.

$$= \frac{1980000}{H_1} = \frac{1980000}{878806{\cdot}6} = 2{\cdot}25 \text{ pounds.}$$

$$A = \text{B.T.U. per horse-power per hour} = \frac{2545}{\text{Efficiency}} = 9960{\cdot}9.$$

B' = pounds of working steam per horse-power per hour for efficiency unity.

$$= \frac{1980000}{H_1'} = \frac{1980000}{1046596} = 1{\cdot}89 \text{ pounds.}$$

C = pounds steam per horse-power per hour total jacket and cylinder for actual efficiency.

$$= \frac{B}{\text{Efficiency}} = 8{\cdot}8 \text{ pounds.}$$

C' = pounds working steam per horse-power per hour actual efficiency.

$$= \frac{B'}{\text{Efficiency}} = \frac{1{\cdot}39}{{\cdot}2555} = 7{\cdot}4 \text{ pounds.}$$

W = equivalent water-rate from and at 212° F.

$$= \frac{A}{966{\cdot}069} = 10{\cdot}3.$$

F = fuel per horse-power per hour

$$= \frac{A}{\text{B.T.U.}} \text{ per pound coal} = 10000.$$

= also, pounds steam per horse-power for actual efficiency of engine, divided by pounds coal per pound steam, in this case assumed at 9 pounds,

$$\frac{99609}{10000} = {\cdot}996 \text{ pound.}$$

$F' = \frac{C}{9} = \frac{8\cdot8}{9} = \cdot978$ pound.

D = piston displacement per horse-power per hour.
$= C\,v_2$ cubic feet $= 8\cdot8 \times 52\cdot89 = 465\cdot4$.

$D' = \frac{D}{144} = 3\cdot25$ cubic feet displacement per horse-power per minute.

r = ratio of expansion.

$= \frac{v_2}{v_1} = \frac{52\cdot89}{1\cdot167} = 45\cdot3$.

(b) Non-Condensing Type.

$p_1 = 400 \times 144 = 57600$ pounds per square foot, absolute.
$v_1 = 1\cdot167$ cubic feet volume at cut-off at pressure p_1.

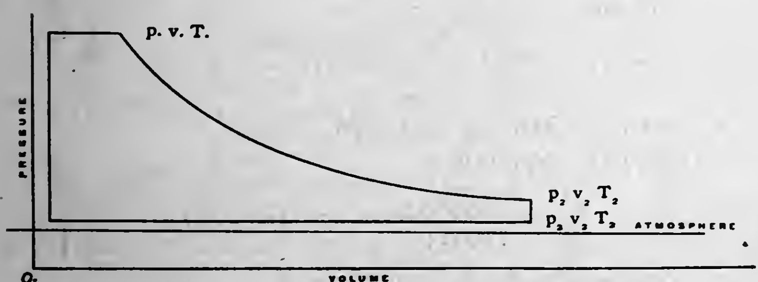

FIG. 8.—Rankine cycle. Jacketed cylinder.

$T_1 = 905\cdot92°$ F. absolute temperature at cut-off.
$p_2 = 21 \times 144 = 2304$ pounds per square foot, absolute.
$v_2 = 18\cdot84$ cubic feet volume at pressure p_2 of a pound of saturated steam.
$T_2 = 691\cdot565°$ absolute F. temperature saturated steam at $p_2\,v_2$.
$p_3 = 16 \times 144 = 2304$ pounds per square foot, absolute.
= back pressure.
$T_4 = 200 + 461 = 661°$ F. absolute temperature feed-water.
$J = 778$ foot-pounds per heat unit.
$a = 1117850$ foot-pounds, a constant.
$b = 544\cdot5$ foot-pounds, a constant.
λ_1 = total heat of evaporation per pound steam above 32°.
$= 1217\cdot7$ B.T.U.

q_4 = heat in feed-water above 32° F.
$= T_4 - (4 - 3) = 661 - 493 =$ B.T.U. $= 168$.

r = ratio of expansion.

$$= \frac{v_2}{v_1} = \frac{18 \cdot 84}{1 \cdot 167} = 16 \cdot 14.$$

H_1 = heat per pound steam at boiler in foot-pounds.
$= H_1 +$ heat received from the jacket.

$$= J\,(T_2 - T_4) + a\left(1 + \log._e \frac{T_1}{T_2}\right) - b\;T_1.$$

$= 778\,(300 \cdot 565) + (1117850 \times 1 \cdot 27) - (544 \cdot 5 \times 905 \cdot 92).$
$= 233839 \cdot 5 + 1419669 \cdot 5 - 493273 \cdot 4.$
$= 1160235 \cdot 5.$

U = net work done in foot-pounds per pound "working steam."

$$= a\,\log._e \frac{T_1}{T_2} - b\,(T_1 - T_2) + v_2\,(p_2 - p_3).$$

$= 30189 \cdot 5 - 116719 + 13264 \cdot 8.$
$= 198365 \cdot 3$ foot-pounds.

$$\text{Efficiency} = \frac{U}{H_1'} = \frac{1983653}{1160235 \cdot 5} = 17 \cdot 9 \text{ per cent.}$$

B = pounds steam per horse-power per hour at boiler, inclusive of jacket-steam, for efficiency unity.

$$= \frac{1980000}{H_1} = \frac{1980000}{816666 \cdot 6} = 2 \cdot 42 \text{ pounds.}$$

B' = pounds of working steam per horse-power per hour for efficiency unity.

$$= \frac{1980000}{H_1'} = \frac{1980000}{1 \cdot 1602355} = 1 \cdot 707.$$

A = B.T.U. per horse-power per hour for actual efficiency.

$$= \frac{2525}{\text{Efficiency}} = \frac{2525}{\cdot 179} = 14220.$$

$$\text{M.E.P.}' = \frac{U}{r\,v_1} = \frac{U}{v_2} = \frac{198365 \cdot 3}{18 \cdot 84} = 10529 \text{ pounds per square foot.}$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} = 73{\cdot}1 \text{ pounds per square inch.}$$

C = pounds steam per horse-power, total for both jacket and cylinder, for actual efficiency.

$$= \frac{B}{\text{Efficiency}} = \frac{2{\cdot}42}{{\cdot}179} = 13{\cdot}5 \text{ pounds.}$$

C' = pounds "working steam" per horse-power per hour, actual efficiency.

$$= \frac{B'}{\text{Efficiency}} = \frac{1{\cdot}707}{{\cdot}179} = 9{\cdot}5 \text{ pounds.}$$

W = equivalent water-rate from and at 212° F. $= \dfrac{A}{966{\cdot}069}$

$$= \frac{14220}{966{\cdot}069} = 14{\cdot}7 \text{ pounds.}$$

F = fuel per horse-power per hour =

$$\left(\frac{A}{\text{B.T.U. in 1 pound}}\right) = \frac{A}{10000} = 14{\cdot}22.$$

$$F' = \left(\frac{C}{\text{pounds water per pound coal}}\right) = \frac{13{\cdot}5}{10} = 1{\cdot}35 \text{ pounds.}$$

D = piston displacement per horse-power per hour $= C\,v_2$ $= 254{\cdot}34$ cubic feet.

D' = piston displacement per horse-power per minute $= \dfrac{D}{60} = 4{\cdot}24$ cubic feet.

SUMMARY.

IDEAL STEAM-ENGINE CYCLES; $p_1 = 400$ POUNDS PER SQUARE INCH.

	Carnot Cycle.		Rankine Non-Conducting Cycle.		Rankine Jacketed Cycle.	
	Condensing.	Non-Condensing.	Condensing.	Non-Condensing.	Condensing.	Non-Condensing.
r	91·23	17·85	35·3	13·7	45·3	16·14
v_2	106·45	20 83	41·2	16·06	52·89	18·84
p_2	288	2,304	1,008	3,024	1,008	3,024
T_2	587·3	677·347	639·9	691·56	639·94	691·56
H_1	620,797	620,797	898,806	816,666	878,806	816,666
U	218,332	157,062	250,470	169,937	267,420	198,365
Efficiency, per cent. (computed)	35·17	25·3	28·5	20·82	25·55	17·9
M.E.P.′, pounds per square foot	2,050	7,540	6.079	10,581	5,056	10,529
M.E.P.″, pounds per square inch	14·2	52·4	42·2	73·48	35·11	73·1
A, B.T.U. per horse-power per hour	7,236	10,059	8,930	12,235	9960·9	14,220
B, pounds steam per horse-power per hour for efficiency = 1·	3·19	3·19	2·36	2·42	2·25	2 42
C, pounds steam for computed efficiency	9·07	12·6	8·28	11 68	8·8	13·5
W, "water-rate" from and at 212° F.	7·49	10·41	9·24	13·66	10·3	14·7
F, pounds fuel for computed efficiency	·83	1·15	·92	1·168	·978	1·35
D, piston displacement per I.H.P. per hour	976·1	262·46	341·1	187·58	465·4	254·3
D', piston displacement per I.H.P. per minute	16·27	4·374	5 68	3·126	3·25	4·24
p_1, pounds per square foot	57,600	57,600	57,600	57,600	57,600	57,600
p_3, pounds per square foot	288	2.304	288	2,304	288	2,304
T_1 (absolute)	905·92	905·92	905·92	905·92	905·92	905·92
T_3 "	587·3	677·347	587·3	677·347	587·3	677·34
T_4 "	905·92	905·92	581·	661·	581·	661·

The Ranges of the Efficiencies computed as obtainable in these ideal cases—which efficiencies are especially important and interesting as constituting the limits toward which the engineer seeks to approximate, while knowing that it is impossible to pass them and impracticable to secure even a very close correspondence in the operation of his real engines—may be noted in the succeeding tables. The pressures

adopted for prime steam are from 150 pounds to 500; *i. e.*, from what is now coming to be a familiar pressure up to a tension which very possibly may prove to be beyond that of profitable utilization in the real engine for a long time to come. The terminal pressures are those due the ratios of expansion specified, and the back-pressures are as low, and, therefore, the efficiencies as high, as modern practice justifies us in expecting for the ideal cases representative of the most successful practice. These figures may be profitably compared with those computed by Rankine, at the middle of the nineteenth century, as corresponding to the cycle of the steam-engine of that date.* The economical gain by the reduction of the back-pressure to the figures now attainable, with such good design and construction as has been readily secured in recent years, is seen to be very considerable. Ample port-area and a tight condenser are obviously elements of economy which it is well worth while to insure.

CARNOT CYCLE.

IDEAL CASE; $p_2 = p_3 = 2$; CORRESPONDING TO $T_2 = 587°$.

	Case I.							
p_1	150	200	250	300	350	400	450	500
T_1	819·2	811·6	861·9	878·36	892 9	905·92	917·6	928·4
r	44·8	57·8	70·4	82·63	94·6	106·5	118	129·6
V_2	133	130·4	128·4	126·83	125·4	124·2	123·3	122
H_1	671,000	656,000	646,c97	636,604	628,219	620,797	613,000	607,618
U	190,000	198,500	205,000	210,079	218,900	218,500	221,0c0	272,000
E	28·3	30·3	31·9	33·1	34·2	35·1	36·	36·7
M.E.P.′ . . .	1,427	1,522	1,604·9	1,695	1,712·1	1,758·2	1,800	1,820
M.E.P.″ .	10·01	10·56	11·13	11·55	11·85	12 2	12·5	12·7
A	9,000	8,430	7,986	7,730	7,450	7,236	7,050	6,934
B	2·95	3·02	3·08	3·11	3·15	3·19	3·23	3·26
C	10·45	9·98	9·69	9·4	9 2	9·0	8·94	8·89
W	9·32	8·73	8·27	7·93	7·73	7·49	7·32	7·19
F	·90	·832	·799	·773	·745	·724	·705	·698
D	1,390	1,300	1,236	1,190	1,157	1,115	1,100	1,090
D'	22·8	21·7	20·6	19·9	19·28	18·58	18·3	18·1

* Thurston's "Manual of the Steam-Engine," Vol. I, § 117.

CARNOT CYCLE.

IDEAL CASE; $p'_2 = p'_3 = 16$; NON-CONDENSING; $T'_2 = 677{\cdot}35$.

Case II.

p_1	150	200	250	300	350	400	450	500
T_1	819·22	842·63	861·88	878·376	892·96	905·92	917·62	927·2
r	7·18	9·25	11·3	13·23	15·1	17·05	18·8	21·02
V_2	21·27	20·87	20·56	20·3	20·07	19·89	19·627	19·51
H_1	670,324	657,080	646,097	636,641	628,150	620,797	613,935	607,618
U	115,966	128,880	138,264	145,727	151,800	157,062	160,728	164,061
E	17·3	19·69	21·4	22·9	24·2	25·3	26·5	27·1
M.E.P.′ . . .	5,450	6,175	6,730	7,178	7,570	7,865	8,159	8,360
M.E.P.″ . .	38	42·8	46·6	49·09	54·2	54·6	56·6	57·0
A	14,710	12,990	11,886·9	11,123	10,530	10,059	9721·16	94·25
B	2·95	3·02	3·06	3·2	3·16	3·19	3·24	3·26
C	17·05	15·35	14·3	13·6	13·08	12·6	12·22	12·07
W	15·3	13·43	12·3	11·5	10·9	10·4	10·06	9·47
F	1·48	1·298	1·19	1·112	1·053	1·01	·972	·941
D	353	321	294	278·2	262·5	262·4	240	237·5
D'	5·89	5·35	4·91	4·63	4·37	4·34	4·03	3·92

RANKINE'S NON-CONDUCTING CYCLE.

IDEAL CASE; $p_2 = p_3 = 2$; CONDENSING; $T_2 = 587°$.

Case III.

p_1	150	200	250	300	350	400	450	500
T_1	819·22	842·63	861·88	878·369	892·96	905·9	917·62	927·2
r	14·87	19·34	25·	27·4	31·4	35·4	39·17	43·02
V_2	44·04	43·25	42·6	42·06	41·55	41.25	40·82	40·5
H_1	858,289	863,813	868,411	872.323	875,827	878,890	881,707	885,000
U	197,624	212,305	223,805	233,120	232,231	242,042	256,526	262,050
E	23	24·5	25·87	26·7	26·5	27·5	29·09	29·6
M.E.P.′ . . .	4,521	4,908	5188·7	5,260	5,583	5,875	6,170	6,375
M.E.P.″ . .	31·16	34·2	35·5	36·6	38·77	40·75	42·64	45·5
A	11,065	10,386	9,910	9,875	9,603	9,254	8,748	8,600
B	2·3	2·29	2·28	2·27	2·26	2·25	2·25	2·24
C	10·	9·35	8·88	8·52	8·54	8·36	7·7	7·57
W	11·4	10·7	10·3	10·2	9·9	9·2	9·0	8·9
F	1·107	1·03	·991	·987	·96	·925	·875	·843
D	440·4	397·	387·1	376·2	355·	328·	316·	306·3
D'	7·3	6·7	6·4	6·2	5·9	5·6	5·3	5·1

RANKINE'S NON-CONDUCTING CYCLE.

IDEAL CASE; $p_2' = p_3' = 16$; NON-CONDENSING; $T_2' = 677{\cdot}35$.

Case IV.

p_1	150	200	250	300	350	400	450	500
T_1	819·2	842·63	861·88	878·37	892·96	905·9	917·62	928·4
r	5·64	7·28	8·91	10·44	11·9	13·4	14·88	16·3
V_2	16·7	16·4	16·2	16·03	15·79	15·69	15·45	15 35
H_1	796,049	803,500	805,000	809,898	813,585	816,000	821,000	822,500
U	126,555	142,720	151383·76	164,457	169,959	177,380	186,152	192,820
E	15·9	17·3	18·92	19·9	20·8	21·9	22·7	23·4
M.E.P.′ .	7,754	8,460	9,219	10,200	10,763	10.940	11.310	12,540
M.E.P.″ . .	52·2	58·8	64·02	70·5	74·7	78·7	83·3	87 2
A	16,006	14,750	13,370	12,794	12,188	11,620	11,201	10,870
B	2·4	2·47	2·46	2·44	2·44	2·45	2·41	2·41
C	15·7	14·2	13·6	12 5	12·2	11·6	10·6	10·2
W	16·58	15·28	14·02	13 6	12·6	12·03	11·5	11·2
F	1·6	1·46	1·35	1·27	1·21	1·16	1·12	1·10
D	246·07	233·9	214·75	195·0	191·5	181·	165·06	159·6
D'	4·58	3·89	3·57	3·25	3·19	3·12	3·0	2·66

RANKINE'S JACKETED CYCLE.

IDEAL CASE; $p_2 = p_3 = 2$; CONDENSING; $T_2 = 587°$.

Case V.

p_1	150	200	250	300	350	400	450	500
T_1	819·2	842·6	861·88	878·37	892·96	905·92	957·62	928·4
r	17·9	23·5	29·	34·4	39·9	45·3	50·76	56·1
V_2	52·89	52·89	52 89	52·89	52·89	52·89	52·89	52·89
H_1	858,289	863,843	868,411	872,323	875,794	878,890	881,707	884 197
U	215,400	236,900	251,555	264 900	—	284,560	291,855	295,600
E	21·3	23·3	24·5	25·5	25·8	26·7	27·3	28·2
M.E.P.″ . .	28·7	31·1	32·9	34·7	3	37·2	38·3	39·2
H_1'	995,526	1,013,915	1,040,650	1,040,806	1,055,534	1,060,938	—	1,072,853
A	12,177	10 920	10,595·3	10,000	11,162	9,520	9,318·9	9,155
B	2·30	2·29	2·28	2·27	2·26	2·25	2·24	2·23
B'	1 976	1·95	1·93	1·91	1·87	1·86	1·85	1·84
C	10·6	9·77	9·30	8·9	8·7	8·42	8·24	8·06
C'	9·22	8·39	7·87	7·45	8·24	6 99	6·75	6·71
W	12·6	11·38	10·77	10 35	—	9·85	9·76	9·60
F	1·21	1·092	1·05	1·0	—	·952	·944	·930
D	431	425	416·5	394	—	370	358	351
D'	7·97	7·39	6·94	6·57	—	6·0	5·96	5·86

RANKINE'S JACKETED CYCLE.

IDEAL CASE; $p_2' = p_3' = 16$; NON-CONDENSING; $T_2' = 677 \cdot 35$.

Case VI.

p_1	150	200	250	300	350	400	450	500
T_1	819·2	841·63	861·88	878·37	892·96	905·92	917·62	928·42
r	6·36	8 32	10·32	12·58	14·21	16·15	18·02	20·0
V_2	18·84	18·84	18·84	18·84	18 84	18·84	18·84	18·84
H_1	795,894	801,600	806,171	810,084	813,585	816,666	819,234	821,988
U	129,240	143,698	166,529	178,878	181,054	198,365	206,734	211,150
E	14·8	16·9	18·2	19·25	20·0	20·9	21 5	22·1
M.E P.′. . .	6,880	8,140	8,850	9,500	10,060	10,540	10,973	11,200
M E.P.″ . .	47·3	56·5	61·4	65	70·1	73·18	76·20	78·84
H_1'	881,868	903,990	912,666	930,750	940,878	950,445	958,241	964,840
A	17,370	15,111	14,411	13,200	12,710	12,096	11,798	11,500
B	2·49	2·47	2·46	2·45	2·43	2·42	2·41	2·40
B'	2·24	2·19	2·16	2 13	2·10	2·08	2·06	2·05
C	17	14·93	13·56	12·7	12·07	11·52	11·2	10·9
C'	15·35	13·0	12·54	11·05	10·9	9·98	9·57	9·32
W	17 8	15·64	14·48	13·6	13·07	12·8	12·2	11·9
F	1·77	1·46	1·398	1·32	1·27	1·20	1·18	1·16
D	267	243·1	230	208	197·8	188	180·2	177
D'	4·77	4·08	3·88	3·47	3·29	2·99	2·92	2·9

CONCLUSION.

En résumé, each standard has its peculiar use, thus:

(1) *The Joule Equivalent, taken as the absolute standard*, gauges the efficiency of the system in an absolute measure, and permits the comparison of the cycle with that of an imaginary perfect engine working between the initial temperature and the absolute zero, converting all heat supplied into mechanical energy, with efficiency unity. It enables us, by such a comparison, to ascertain the total magnitude of all wastes, thermodynamic or other, and the defects of the cycle chosen.

(2) *The Carnot Cycle, taken as a relative standard*, giving the magnitude of the efficiency of the so-called "perfect engine" between the limits of temperature of the case compared with it, permits a measure to be obtained of the wastes

other than the necessary thermodynamic losses, and fixes the limit of perfection of the real engine.

(3) *The Rankine Adiabatic Cycle, taken as a relative standard,* affords a means of similarly gauging the wastes of the engine, aside from those due the imperfection of the cycle, and measures the degree of perfection of the real engine of similar geometric cycle.

In making this comparison, the ideal cycle is made to correspond as closely as practicable with that of the real engine. It can be modified, if found desirable, by the introduction of the compression-line, in cases in which clearance and compression are important.

(4) *The Rankine "Jacketed-Engine Cycle,"* in the same way, measures the extra-thermodynamic wastes of the real jacketed engine, and gauges its approximation to the purely thermodynamic machine. In this case the real engine may be made to approximate the performance of the ideal comparatively closely.*

Each standard, absolute or relative, thus finds its appropriate place and purpose. The computed quantities in the tables which have been given, affording standards for special cases under each class, give measures of the efficiencies which the engineer must accept as limits toward which he may approach as he improves his engines, but which he can never fully attain.

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* It is to be noted, however, that jacketing the ideal is ideally wasteful. The gain by the use of the jacket in practice is well understood to be due to the fact that it is a method of checking internal cylinder condensation, thus thermally gaining, usually, more than it itself wastes thermodynamically.

OBSERVATIONS ON MAGNETIZED WATCHES.*

By William T. Lewis,
Member of the Institute, President of the Horological Society of Philadelphia.

In this age of electricity and electrically-propelled machinery, the wearers of watches are constantly coming in contact with sources of danger to the fine time-keeping qualities of their vest-pocket companions.

Non-magnetic watches are those in which the balance-wheel, hair-spring, roller-table, lever and 'scape-wheel are made of metals which are neither magnetic nor diamagnetic; and such watches have been brought to a high degree of perfection, some having been produced which have had nearly as close a rate as the best of those which are not non-magnetic. In addition to this, several varieties of anti-magnetic shields have been placed on the market, which are said to be more or less effectual in preventing magnetism in watches.

However, it is of the ordinary watch (which is not non-magnetic) that I wish to speak to-night. In such a watch the hair-spring, roller-table, lever and 'scape-wheel are made of steel either wholly or in part. A watch of this kind will become magnetized by being brought into too close proximity to a powerful magnetic field, such as is developed in a dynamo or a motor; or by coming in contact with, or by being brought near to, an ordinary magnet; and there are also other sources of magnetic and electro-magnetic influence which will act injuriously upon a watch.

It will be seen that as all the steel parts of the watch be, come permanent magnets under the conditions mentioned-each steel part thus assumes definite polarity and tends to place itself in a north-and-south position like a compass. Moreover, each steel part attracts and is attracted by, and repels and is repelled by, every other steel part in the watch.

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* Read at the stated meeting of the Franklin Institute, November 18, 1896.

The influence of these magnets, one on the other, and the influence of the earth's magnetism on the several parts, seriously impede their freedom of motion, thereby affecting the rate of the watch, sometimes even causing it to stop.

A simple method to detect the presence of magnetism in a watch is to place a small compass (one with a very fine sensitive needle about 0·8 centimeters in length) directly over the balance-wheel and upon the "bridge" which supports it. If the needle oscillates it is evident that the watch is magnetized. However, this test is not conclusive, as the

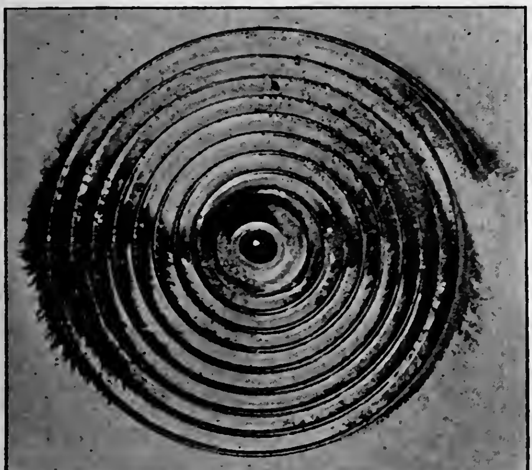


FIG. 1.

hair-spring may be magnetized, and, under certain conditions, the needle will not show it.

I am not aware that any one has yet called attention to the fact that the hair-spring or the main-spring of a magnetized watch contains "consequent magnetic poles," and I will endeavor to show that such is a fact, by means of the following experiments which I have made:

A hair-spring, which was placed in a powerful electro-magnetic field, was afterwards dipped in iron filings and photographed. The result is shown in *Fig. 1*.

On testing its polarity (to do which it was necessary to

straighten the hair-spring out into a long riband, similar to its condition before it was coiled into shape) it was found to contain numerous consequent poles, as shown in *Fig. 2.*

In a watch the outer end of the hair-spring is stationary, while the inner end is fastened to a collet which vibrates with the balance-wheel. As the balance-wheel makes approximately one and one-half revolutions at each vibration (*i. e.*, 270° on each side of the "dead center"), it is evident that at the moment when a watch becomes magnetized, the hair-spring will probably be at some other position than that of rest.

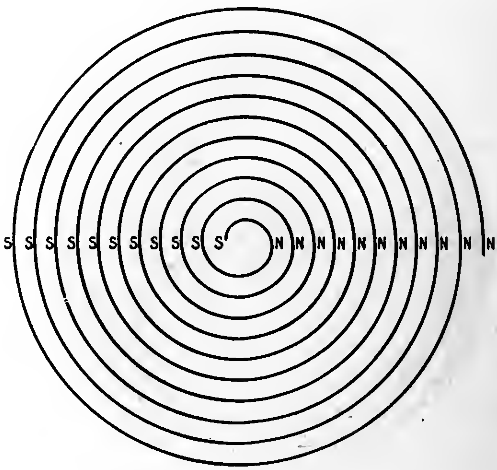


FIG. 2.

Fig. 3 shows a hair-spring which was magnetized when the balance-wheel had arrived at the end of its arc of vibration, and photographed (having been dipped in iron filings) after it had returned to its position of rest. The poles are not in the same straight line as in *Figs. 1* and *2*, as is shown by the iron filings grouping themselves in a different manner.

The polarity was found, on testing, to be as shown in *Fig. 4*, the dotted lines, passing through the poles, forming geometric curves.

Fig. 5 shows a form of demagnetizer in common use, which consists, essentially, of a helix *F*, switch or key *C*,

the commutator *A*, which serves the purpose of changing the polarity of the helix, and the flexible cord *E* to connect the machine with a battery or with an electric light circuit. If the current be alternating, the commutator can, of course, be dispensed with.

In operating with this machine the key is pressed down, and the commutator is turned by means of the crank *D* at a speed of about 150 revolutions per minute. The watch is then passed slowly through the helix, the speed of the crank being kept uniform in the meantime.

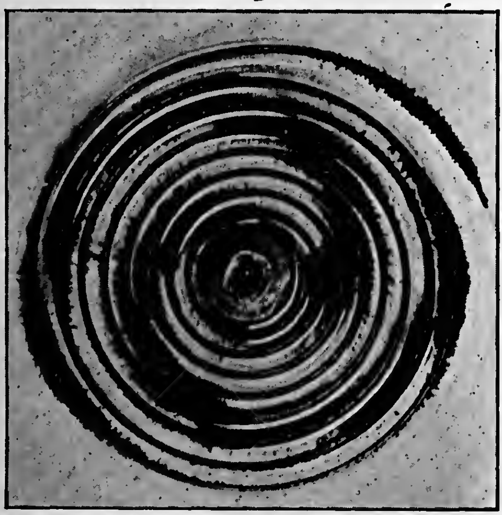


FIG. 3.

With the ordinary demagnetizer the hair-spring of a watch is very difficult (if not impossible) to demagnetize without treating it separately, as it possesses about four times as many magnetic poles as it contains coils. The poles are difficult to locate, as the coils are not more than 0·15 millimeters to 0·25 millimeters apart in watches of the usual size. The whole diameter of the spring may be from 5 millimeters to 8 millimeters.

Then, also, the vibration of the hair-spring under the action of the demagnetizer seems to prevent the proper demagnetizing effect from being produced.

Good results, however, can be secured by placing the hair-spring on a watch-glass and covering it with very viscous oil or with a drop of melted beeswax, and placing it in that condition under the action of the demagnetizer, keeping the watch-glass horizontal and, at the same time, causing it to revolve about its center. The oil or wax can afterwards be dissolved in benzine and the hair-spring cleaned.

Demagnetizers of various construction have been contrived; but I do not know of any which will *thoroughly* demagnetize all the parts of a watch *unless the watch be taken apart* and each steel piece submitted separately to the action

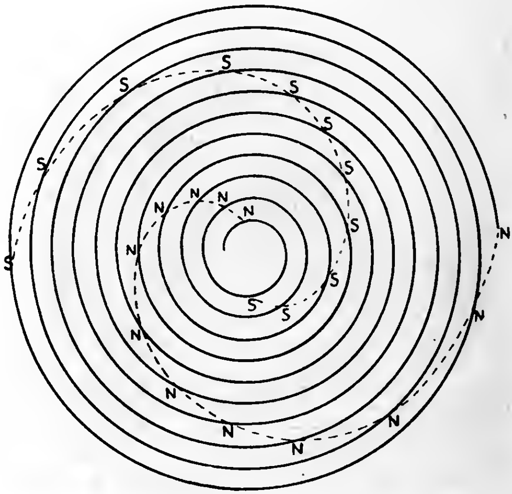


FIG. 4.

of the demagnetizer, testing each piece each time it is passed through the machine in order to ascertain to what extent the magnetism has been removed, and again passing it through the helix in another position if it be found to still contain magnetism.

If, in passing the watch through the helix (without taking it apart), any steel part be so situated in the watch, and be also magnetized in such a manner that its magnetic axis be *otherwise* than parallel to the axis of the helix, it will be seen that such part will not be thoroughly demagnetized.

Fig. 6 shows a view of the helix, in section. The hands of the watch denote the hour of 9 o'clock. If, before the watch was passed through the demagnetizer, one end of the minute-hand was a north-seeking pole, and the other end a south-seeking pole, it is evident that the minute-hand will now be demagnetized.

But to demagnetize the hour-hand, the watch would need to be turned so that the magnetic axis of the hour-hand would be parallel to the axis of the helix. There is also the steel arbor which carries the hands, the axis of which is at right angles to the planes in which the hands

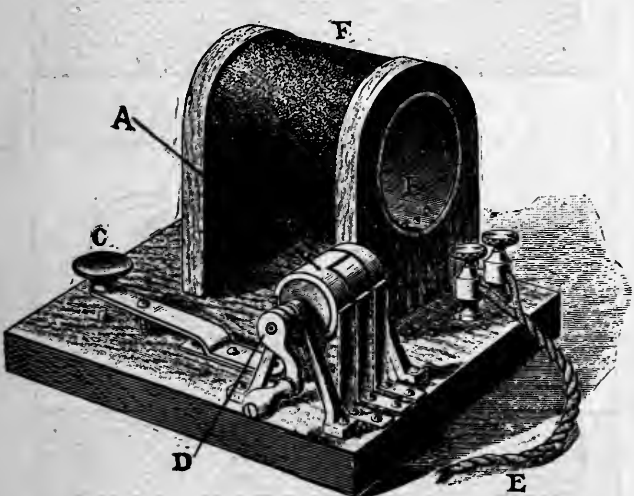


FIG. 5.

lie. Then there are other steel parts which lie in other planes; so that it would seem necessary to cause the watch to revolve in such a manner that every plane shall be subsequently brought into a position parallel to the axis of the helix.

To this end I am now constructing a demagnetizer, which I may have the opportunity of exhibiting at some future meeting; but which I will now describe in order that I may have the advice of others better versed in the mysteries of electricity and magnetism than myself.

In *Fig.* 7, *A* is a watch to be demagnetized, mounted on a

circular disk *B*, being held in position by the clutches *C C*, and a third clutch which is not shown. The disk is caused to revolve by the bevel gears *E E'*, which receive their motive power from the gear *G*. The gear *H* is stationary; while the frame *K K'* is mounted on the revolving shaft *L*, driven by the bevel gear *M M'*, which in turn is caused to revolve by a belt from a pulley *N*, on the shaft *O*, to the pulley *P*, on the shaft *Q*, of the small motor *R*, which is driven by the battery *S*. This motor will be enclosed in an

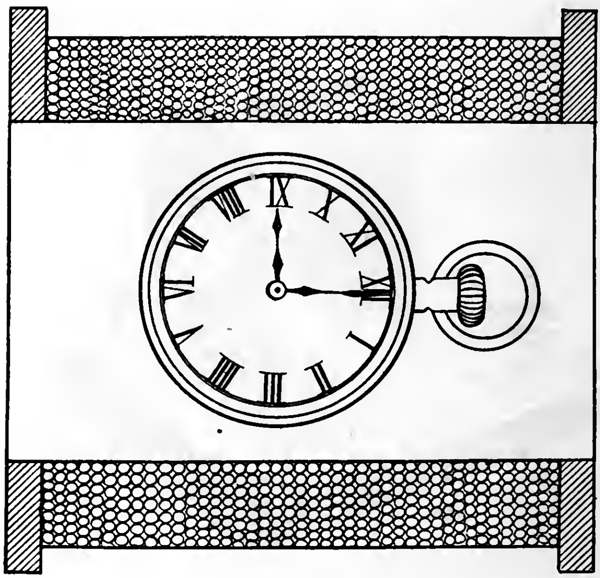


FIG. 6.

iron cylinder to insulate it magnetically, and so prevent its influence on the watch. A clock-work could, of course, be used instead of the motor. The head of the carriage is shown separately in *Fig. 8*.

It will be seen that the revolving of the frame *K K'* around the axis of the shaft *L* will cause the gear *G* to revolve around the gear *H*. At the same time the revolving of the gear *G* on its own axis will cause the disk *B* to revolve around its own center.

Thus the watch will revolve around its vertical axis (*i. e.*,

the axis of the shaft *L*) and around its horizontal axis (the axis of the shaft *D*) at the same time. By having one tooth more (or less) in the gear *G* than in the gear *H*, the watch

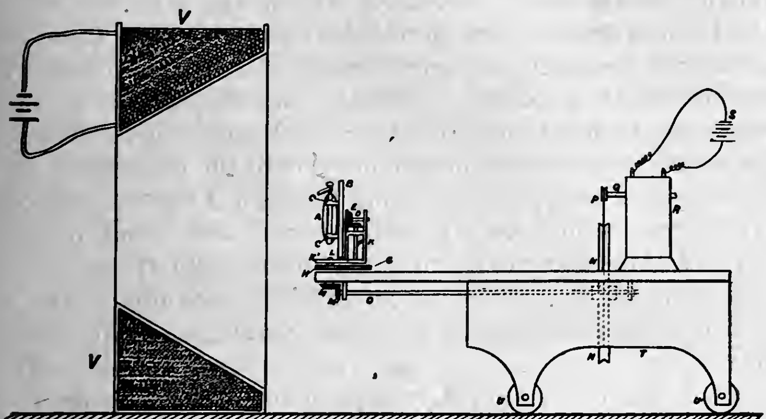


Fig. 7.

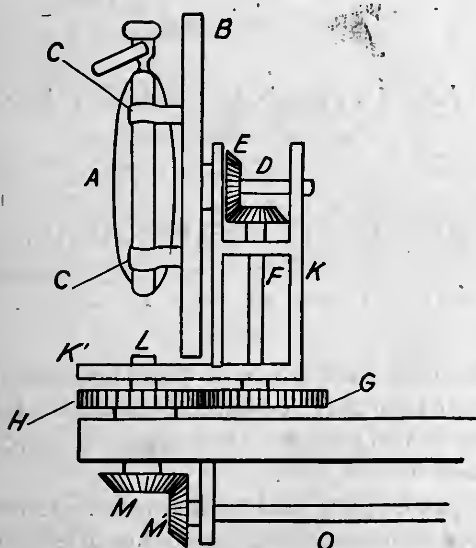


Fig. 8.

will be continually placed in new and different positions, until the gears *G* and *H* arrive in the same relative positions in which they were at the start.

The carriage *T* is mounted on wheels *U U'*, in order that the watch may be slowly advanced into the helix *V* to its smaller end, and again slowly withdrawn. It should be withdrawn to a distance of several feet from the helix.

The helix, as shown in section, is given this form in order that the electro-magnetic effect of the current on the watch may be gradually increased and diminished as the watch is advanced into the helix and withdrawn. When the watch has reached the smaller end of the helix there are more lines of magnetism passing through it for the reason that there are more coils of wire around and about it, and the coils are also nearer to it. Thus the polarity of each steel part of the watch is successively changed with a gradually diminishing force as the watch is slowly withdrawn, until every piece of steel in it is brought back to its normal condition. Such is my theory, and I hope my machine will be successful. In the meantime I will be glad to receive any suggestions.

ELECTRICAL SECTION.

Stated Meeting, November 25, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

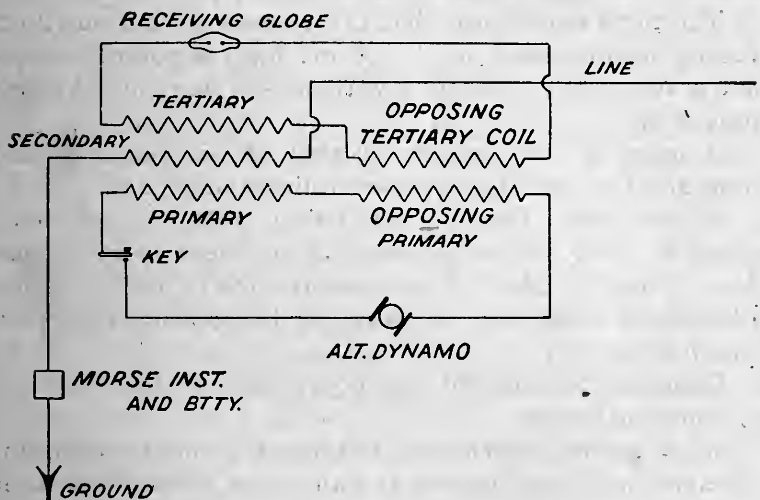
AUXILIARY TELEGRAPHY.

By DR. I. KITSEE, Member of the Institute.

Telegraphy in the last score of years has made such rapid progress that it is hardly possible to increase the capacity of a line wire, or to facilitate the ease with which messages are transmitted or received.

We have quadruplex and multiplex systems. We can send a number of messages in opposite directions; but we cannot, if the terminals of a line are used for transmitting or receiving one kind of messages, transmit messages from and to intervening stations of such line without interfering with the telegraphic communications of the terminal offices.

And the lack of a system permitting communication between intervening stations, at one and the same time, when the line is being used by the terminal offices, is generally a great source of inconvenience, but specially so on such lines running along railways, where the general business of the telegraph company must give preference to the business of the railway company. On such lines it very often happens that the main offices have to suspend business altogether for a considerable length of time in the midst of the busiest part of the day because the intervening railway stations have to exchange messages about some more or less impor-



tant point pertaining to the railroad service, and the device as presented to-night to your kind inspection is designed to overcome this difficulty.

We have here represented two telegraphic stations equipped with the Morse system, the sounders, and also with the Auxiliary system, both stations joined together through wire-resistance of 2,500 ohms, equal to about the resistance of the ocean cable. The diagram shown herewith will illustrate the instruments used, as well as the electrical connections of same, and the gentleman assisting me will, as the evening progresses, send and receive messages over this

line with the aid of the auxiliary device, as well as the Morse, and the ease with which such messages are simultaneously transmitted will, no doubt, be apparent to you.

The first requisite of such device to be worked from intervening stations at one and the same time, when the line is used by terminal stations, is that there shall not be inserted in the line large resistance or batteries, or other generators of electricity which may come in conflict with the batteries of the terminal stations.

The second requisite is that the current transmitted from the main stations shall not actuate the receiving or sending instruments of intervening stations, and *vice versa.*

The third requisite is that the current used from intervening stations shall not be of too high a potential, so as not to injure the insulation with which common lines are provided.

It must also be understood that no additional connections shall be introduced between line and ground.

It is believed that the "Auxiliary Telegraph System" about to be described answers all of these requirements. Also, it has the great advantage that it is in itself a duplex, allowing the sending of messages in opposite directions simultaneously.

Generally considered, the equipment of the Auxiliary system consists of:

(1) A sending device, consisting of a small alternating dynamo, or, if such be not at hand, of a mechanical alternator, in connection with some batteries in the circuit, in which is placed a sending key and the primary of a convertor.

The secondary of this convertor is connected in series with the line, and the tertiary of this convertor is locally connected with the vacuum globe, which acts as a receiver.

The primary, as well as the secondary of the convertor, should be a low-resistance one. The tertiary coil should be wound in such manner as to increase the E.M.F. to an extent necessary for producing the glow in a vacuum globe.

Each of the stations, the sending as well as the receiving station, is also provided with a second primary, connected in series with the first primary. This second primary is

placed into a coil equal in its inducing capacity to the tertiary first spoken of. The terminals of this coil, which I call the second or opposing tertiary, are connected in opposition to the first coil with the receiving vacuum globe.

This second series of coils is necessary for the duplexing of the system.

Following is a short description of the mode of sending messages according to this—the Auxiliary system:

At the sending station, the operator connects his first primary coil through his sending key with the source of electricity. With the aid of this key he sends through his primary coil currents of electricity. These impulses, which are alternating, induce impulses in the secondary, corresponding in time to the time of the flow of impulses in the primary. It will be understood that the operator, in opening and closing the key once, does not send a single impulse only through the primary, but a series of impulses, the flow time of which corresponds with the closing time of the key, a dot with its short closing time sending impulses through the primary for a shorter period than a dash with its longer closing time. As far, therefore, as the operator is concerned, he has to manipulate the key as if the current-flow were a constant and not an alternating one.

These alternating impulses in the primary induce alternating impulses in the secondary. These impulses travel over the line, wire or cable, and through the secondary inserted in the line at the receiving station. We, therefore, have, as a result of the sending of a message travelling over the line rapidly alternating impulses of such short duration that the other, *i. e.*, Morse or similar sending or receiving instruments, depending, as they do, on the movement of the armature of an electro-magnetic device, cannot respond and remain practically unaffected by the flow of these impulses. As around each of the secondary coils, sending as well as receiving station, the tertiary coil is wound, it follows that the alternating impulses, travelling through the secondaries, will induce alternating impulses in the tertiaries, and as the coils are wound to the necessary high potential, the generated tertiary impulses

will, if the terminals of the coils are connected to a vacuum tube or device similar in its action, produce in said tube or similar device a glow, corresponding in time to the time of the electric impulses generated through induction—shorter glow-time for dot and longer glow-time for dash.

The office and function of the second primary coil has, so far, not been taken into consideration, and if this system is used only as a simplex one, then the addition of this coil is not necessary; but as set forth above, the object is to con-triplex or duplex the auxiliary of telegraphy, and the prime conditions to be fulfilled in practically carrying out of the method of simultaneous transmission in opposite directions are:

(1) That the receiving instrument at the home station shall remain entirely unaffected by the movements of the transmitting key at that station, while at the same time it shall remain free to respond to the currents transmitted by the key at the distant station.

(2) If this induced system shall be used in conjunction with the usual receiving and sending instruments, which are liable to be opened just at the time of transmission with induced currents, that the same currents shall always be provided with an uninterrupted passage to the ground, at the home station as well as at the distant station.

To fulfil the first condition, is the office and function of the second primary coil. This coil is so wound or connected to the source of current that the alternating impulses flowing through it are capable of inducing in the second tertiary coil impulses of opposite direction from the impulses induced through the action of the secondary coil in the first tertiary.

The necessary adjustment of the inducing influence of one coil on opposing coil can be accomplished:

(1) Through the operation of a rheostat, through the action of which more or less resistance can be thrown into the circuit of the second primary; or,

(2) The second primary can be partially withdrawn from the inner space of the second tertiary.

Supposing now, the adjustment being perfected, the

operator at one station is transmitting a message to the second station.

In depressing his key he sends a multitude of impulses through the primary, inducing thereby a multitude of impulses in the secondary, which multitude of impulses will induce tertiary impulses in the tertiary coil, and will flow over the line into the secondary of the second station, inducing impulses in the tertiary of the receiving station.

Ordinarily, the receiving instruments of both stations, the receiving as well as sending, would answer; but as the depression of the key at the sending station also sends, simultaneously with the sending of the impulses through its first primary, impulses starting at the same time and at the same frequency through its second primary, and as the inducing effect of such impulses is opposite from the induced impulses flowing through its first primary, it follows that both the influence of the first and second primaries on its tertiary are neutralized, and that therefore the receiving instrument at the sending station will not respond.

The proviso of an uninterrupted passage for the induced current is fulfilled by shunting the key and instrument of the Morse, or similar devices, through a condenser.

As stated in the introductory remarks, the alternating current flowing over the line is of such low potential that it would not affect or injure the insulation of a submarine cable, and it is believed that it can be used with impunity on cables as well as land lines.

In conclusion, it can be said that the tests of the chief electrician of one of our foremost telephone companies have established the fact that the leakage and induction from a line traversed by the currents of the auxiliary are not greater than the leakage and induction from a wire traversed by a telephonic current, and that, therefore, the application of this system to existing submarine cables is believed to be a practical one.

[Note.—During and after the reading of the paper, Mr. W. B. Eldridge operated the system by sending and receiving messages on both the Morse and Auxiliary at one and the same time over a single line-wire.—Ed.]

NOTES AND COMMENTS.*

TWENTY-FIFTH ANNIVERSARY OF THE STEVENS INSTITUTE OF TECHNOLOGY.

A noteworthy event in the annals of technical education in the United States will be the forthcoming celebration of the twenty-fifth anniversary of the Stevens Institute of Technology, on the 18th and 19th of February next.

The festivities will consist of a banquet, at the Hotel Waldorf, New York, to which representative engineers and technical educators throughout the country will be invited. On the following day the Institute will be open for inspection, and the methods of instruction, together with the apparatus in the various laboratories, will be explained.

Not the least interesting feature of this exhibition will be the collection illustrating the work of the alumni, and consisting of machinery, apparatus, drawings, etc., representing the product of their activity during the twenty-five years.

The festivities also include a reception, tendered to the faculty, graduates and undergraduates, by Mrs. E. A. Stevens, widow of the founder of the Institute, at Castle Point, Hoboken. A promenade concert and dance in the evening will conclude the celebration.

The Stevens Institute of Technology was founded by the late Edwin A. Stevens, of Hoboken, N. J., and in 1870 the erection of a building was commenced by the trustees, Mrs. E. A. Stevens, Mr. S. Bayard Dod and Mr. W. W. Shippen. Dr. Henry Morton, at that time Secretary of the Franklin Institute, of Philadelphia, was tendered the presidency of the Institute, and gathered a faculty of eight members about him. To this number others have, from time to time, been added as the work of the Institute increased, until at the present time the faculty includes twenty-two professors and instructors. The total number of student graduates is 675, and the number in attendance during recent years has been about 260 each year.

The Stevens Institute has always taken high rank among the institutions devoted to technical education in the United States, and its twenty-five years of successful effort is amply exemplified in the work accomplished by its graduates in all departments of mechanical and electrical engineering.

THE EXPLOSIVE PROPERTIES OF ACETYLENE.

Progressive Age prints the following abstract of some experiments recently completed by Messrs. Berthelot and Vieille, which show that considerable precautions are necessary in dealing with acetylene, particularly in the compressed state. The gas in question is an endothermic body—that is to say, a

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* From the Secretary's monthly reports.

quantity of heat is liberated on decomposing it into its constituents, hydrogen and carbon. Reasoning on this basis, the experimenters determined to try whether the gas could not be detonated by means of a cap of fulminate of mercury. This proved possible, though at atmospheric pressures the explosive wave did not proceed throughout the body of the gas, the decomposition being limited to the immediate neighborhood of the detonation. When, however, the gas was compressed, the experiments showed that it might prove a dangerous explosive. In fact, it was not then necessary to use a detonater, as it was found that the mere heating of the gas by an incandescent platinum wire was sufficient to cause an explosive decomposition of the acetylene. Average figures from a number of experiments made with different degrees of initial compression showed the following rises of pressure:

Initial Pressure. Pounds per Square Inch.	*Maximum Pressure Observed on Explosion. Pounds per Square Inch.*	*Ratio.*
31·7	138·7	4·4
49·4	271·0	5·5
85·1	600·0	7·0
160·0	1,312·0	8·2
301·0	3,028·0	10·1

On opening the steel test tube after an experiment, it was found to be filled with a mass of finely divided carbon agglomerated together by the increase of pressure. The rise of temperature at the moment of explosion was considerable, and in the case of the last of the experiments, referred to above, amounted to as much as 2,750° C. It was, moreover, found possible to detonate liquefied acetylene in the same way, a pressure of over 35 tons per square inch being then attained. The explosion was started, as in the previous cases, by means of a white-hot platinum wire. Dropping a bottle of the liquefied gas, or allowing a heavy ram to fall on it, proved insufficient to detonate the mixture, although when the bottle was broken by the ram a violent explosion occurred. This, however, arose from the combustion of the gas, and thus differed materially in nature from the experiments previously made, in which the acetylene was merely resolved into its elements.

LUCIUM, A NEW ELEMENT.

From London *Nature* we learn that, in the course of researches on monazite sand, M. P. Barrière appears to have come upon a new elementary body, to which he has given the name *lucium*, and which he purposes using for the production of an incandescent gas light similar to that of Auer von Welsbach. Careful investigation has been made of the new and independent character of lucium, in order to prove that its use was not anticipated by the Welsbach patents. The examination showed that while the salts of cerium, lanthanum and didymium form with sodium sulphate insoluble double salts, lucium does not. Thorium and zirconium form insoluble double salts with potassium sulphate; this is not the case with lucium. Yttrium, ytterbium and erbium are not precipitable by sodium thiosulphate, whilst lucium chloride is

precipitable. From glucinium, lucium differs, as its salts are precipitable by oxalic acid. The lines in the spectrum of lucium are special, and only approximate slightly to those of erbium. Erbium oxide, on ignition, appears of a very pure rose-color, and its nitrate is red. On the contrary, lucium oxide is white, slightly grayish, and its nitrate is white. The aqueous solutions of the erbium salts are red or rose-color; those of lucium, even if containing 15 or 20 per cent. of the salt, are almost colorless. These and other reasons seem to show that lucium is a new distinct elementary body. Its atomic weight has been calculated as = 104.

PRODUCTION OF AMBER.

The working of amber in Prussia is a monopoly in the hands of a firm which owns the best two mines, Palmnicken and Kraxtepelle. For the concession the firm, according to Consul Hunt, of Dantzig, pays to the German Government a royalty of 650,000 marks (about $162,000) a year. It is reckoned that this firm has up to now paid no less a sum than $5,000,000 in royalties to the German Government. In addition to the output from the mines in 1895, a good deal of amber was picked up on the beach at Pillau, in the province of East Prussia, being washed up with the seaweed during the prevalence of northwesterly gales. The shore at Pillau after a storm is sometimes covered with a layer of seaweed 3 feet thick, among which the amber is found entangled. Men, women and children find easy and lucrative employment in searching for the amber along this part of the amber coast. The people engaged in this precarious work often earn 30 shillings a day and more. In 1895, about 100 tons of raw amber came to Dantzig to be worked up, as compared with 140 tons in 1894. It was nearly all melted to make lac and varnish. The larger pieces are made into beads, which are sent all over the world. The beads known to the trade as Leghorn corals were in strong demand.—*Scientific American.*

ACETYLENE.

From the *Progressive Age*, we take the following data bearing on the behavior of acetylene, which are credited to the investigations of M. Brevans:

"If ordinary acetylene from carbide be passed through a series of three washing-flasks containing a solution of sulphate of copper, there is no effect perceptible within three hours; but after twelve hours the first flask contains a black-brown, brilliant precipitate, the quantity of which goes on increasing for as much as eight days. This precipitate explodes on shock, friction or heating; and it appears to be a mixture of phosphide and silicide of copper, of sulphate of cupro-acetyle, and a variable quantity of acetylide of copper. Its production appears to depend largely on the presence of ammonia in the crude acetylene gas; and it shows that the crude acetylene contains phosphoreted hydrogen and siliciureted hydrogen. The second flask contains a precipitate which is similar in appearance, but less explosive; and the precipitate in the third flask is not explosive. The explosive precipitate in the

first flask will explode even under water, as, for example, when we try to rub it off the glass with a glass rod.

"As to the explosibility of acetylene there are two opinions: one, that there may be metallic acetylides formed, which act as detonators to the acetylene itself, so that acetylene cannot be used with reservoirs which are capable of being attacked by it; the other, that it can only be exploded when mixed with air, and that the influence of the outside explosions which can set it off cannot travel far through air. In any case, acetylene, at a pressure not much exceeding that of the atmosphere, is not explosive, though it is explosive at pressures above 2 atmospheres; so that there is no reason to fear an explosion through flame running back to a reservoir under a very small excess of pressure. Shock alone does not appear to cause explosion of the gas, only of the acetylides. The alleged poisonousness of acetylene—which has not, as yet, given rise to any accident—would appear to be due to the occasional presence of cyanogen compounds, and is not a feature of pure acetylene. The presence of sulphureted hydrogen in acetylene seems to depend on that of sulphide of aluminum in the carbide of calcium; sulphide of calcium may exist in it without forming this impurity. The blocking of gas jets by acetylene flames seems to be due to the formation of phosphoric acid. If oxygen be not present, acetylene does not attack copper; the oxide must be formed before the acetylide can be produced."

ENGINEERING NOTES.

A means for *preventing the noise made by trains* in passing over iron bridges has been devised by a German engineer named Boedecker. He puts a decking of 1¼-inch planks between the cross girders, resting on 3-inch timbers laid on the bottom flanges. On the planks a double layer of felt is laid, which is fixed to the vertical web of the cross girder. At the connections with the girder a timber cover joint is placed on felt, and two hooked bolts connect the whole firmly to the bottom flange. Four inches of slag gravel cover the decking, which is inclined toward the center of the bridge for drainage purposes. A layer of felt is laid between the planks and the timbers they rest upon, and the iron work in contact with decking and ballast is asphalted. The decking weighs 600 pounds per yard for a bridge 11 feet wide, and costs 23 cents a square foot. It is water-tight, and has proved very satisfactory in preventing noise.

BOOK NOTICES.

Tables Showing Loss of Head Due to Friction of Water in Pipes. By Edmund B. Weston, C.E., Member of the American Society of Civil Engineers, Member of the Institution of Civil Engineers of Great Britain. New York: D. Van Nostrand Company, 23 Murray and 27 Warren Street. 1896. Price, $1.50.

The author here presents two tables of flow in pipes, one referring to pipes with very smooth inner walls, such as lead and brass pipes, from ½ inch

to 3 inches diameter, and the other referring to new cast-iron pipes, from 4 to 60 inches diameter.

The tables give the velocity, entry and friction heads and the discharge in gallons per minute and per twenty-four hours, corresponding to velocities covering a considerable range.

The velocity heads are, of course, calculated by the simple formula:

$$h_v = \frac{v^2}{2g},$$

and the entry head by the formula,

$$h_e = 0{\cdot}505 \frac{v^2}{2g}.$$

In Table 1, the friction head is calculated by the author's formula,

$$h_f = \left(0{\cdot}0126 + \frac{0{\cdot}0315 - 0{\cdot}06\,d}{\sqrt{v}}\right) \frac{l}{d} \frac{v^2}{2g},$$

published in *Transactions* American Society of Civil Engineers, Vol. XXII, 1890, while in Table 2, covering new cast-iron pipes, the two formulas of Darcy,

$$h_f = \left(0{\cdot}017379 + \frac{0{\cdot}0015965}{d} + \frac{0{\cdot}0040723 + \frac{0{\cdot}000020816}{d^2}}{v}\right) \frac{l}{d} \frac{v^2}{2g},$$

$$h_f = \left(0{\cdot}0198920 + \frac{0{\cdot}00166573}{d}\right) \frac{l}{d} \frac{v^2}{2g},$$

are used; the former for velocities less than 0·33 foot per second, and the second for greater velocities.

In Table 1 the friction head is given for 100 feet length of pipe, and in Table 2 for 1,000 feet.

The author, being unable to discover a general formula which would satisfactorily apply to old cast-iron pipes whose walls had become roughened by oxidation, has given a series of coefficients, corresponding to different ages of pipe in years, for use in connection with Table 2.

It will at once occur to engineers that, under certain conditions, cast-iron pipes will sometimes corrode more in two or three years than, under other conditions, in twenty or thirty years; and that it must, therefore, be hazardous to depend upon a table in which the effect is assumed to be proportional merely to the age of the pipe.

For some reason, the columns in the tables are arranged without any apparent controlling idea. The column of mean velocity is, of course—and necessarily—placed first; but then, instead of grouping the three heads together and the two rates of discharge together, we have: first, velocity head; then, discharge in gallons per minute; then, friction head; then, discharge in gallons per twenty-four hours; and, finally, the entry head. T.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 16, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 16, 1896.

JOSEPH M. WILSON, President, in the chair.

Present, 133 members and visitors.

Additions to membership since last report, 10.

The following nominations were made in pursuance of Article VI of the By-Laws:

President	to serve one year, ...	JOSEPH M. WILSON, JOHN BIRKINBINE.
Vice-President	" three years, ...	W. P. TATHAM.
Secretary	to serve one year, ...	WM. H. WAHL.
Treasurer	" " " , ...	SAMUEL SARTAIN.
Auditors	" three years, ...	W. O. GRIGGS.
	To serve for the unexpired term of Samuel H. Needles, deceased, . .	JOHN H. COOPER.

Managers (to serve three years).

GEORGE E. BARTOL,
ARTHUR BEARDSLEY,
HENRY C. BROLASKY,
JAMES CHRISTIE,
F. L. GARRISON,
H. W. JAYNE,
LAWRENCE T. PAUL,
HORACE PETTIT,
JOSEPH M. WILSON.

Committee on Science and the Arts (to serve three years).

WM. M. BARR,
H. F. COLVIN,
THOS. P. CONARD,
SPENCER FULLERTON,
J. M. HARTMAN,
JOHN HAUG,
WM. C. HEAD,
WM. C. HENDERSON,
H. R. HEYL,
G. A. HOADLEY,
LOUIS E. LEVY,
D. ANSON PARTRIDGE,
TINIUS OLSEN,
SAMUEL P. SADTLER,
PAUL A. WINAND.

Vacancies on the Committee of Science and the Arts were filled by the election of A. Langstaff Johnston for the unexpired term of Wm. McDevitt, resigned, and Edgar Marburg for the unexpired term of Wm. N. Jennings, resigned.

Under a suspension of the rules, Prof. F. L. Garrison presented the following preamble and resolution, and spoke in support of them, urging that both the time and opportunity were favorable to the carrying out of the proposed enterprise :

"WHEREAS, the Franklin Institute, for several years, has been desirous of holding a public exhibition, but has been unable to do so, principally because of the want of a building of suitable character and location, available for the purpose ; and

"WHEREAS, it appears that the Franklin Institute, at this time, has the opportunity of securing, on favorable terms for such purpose, the use of the large building about to be erected at Eleventh and York Streets, Philadelphia, by the United Singers of Philadelphia, for the eighteenth annual Sængerfest, to be held in June, 1897 ; therefore,

"*Resolved*, That the Board of Managers of the Franklin Institute be requested to give the matter their prompt and earnest attention, with the view (should it be found feasible and expedient) of making the necessary arrangements for obtaining the use of this building, for holding a public exhibition therein, in the autumn of 1897."

The preamble and resolution were seconded by Mr. G. M. Eldridge, who strongly advocated their passage.

Prof. E. L. Elliott, of Pittsburgh, presented a paper on "The Utilization of Artificial Light." The paper treated the subject partly from the historical point of view, but chiefly with reference to the question of the proper method of securing the most efficient distribution and diffusion of the light. The practical solution of this problem by means of the "Holophane Globes," invented by Blondel and Psaroudaki, of Paris, was made the subject of an interesting demonstration.

Mr. C. Francis Jenkins, of Washington, read a paper describing his lately-devised "Phantoscope," an apparatus designed for exhibiting a series of rapidly-shifting photograph transparencies, so related to one another as to give the impression of objects in motion. At the close of his remarks, the speaker gave a demonstration of the apparatus arranged in connection with a projecting lantern.

Mr. N. Howland Brown exhibited an improved Acetylene Gas Machine, and gave a demonstration of the comparative value of this gas as an illuminant for lantern projections. The demonstrator exhibited the fact that acetylene gave nearly as bright a field as that afforded by the lime light with oxyhydrogen gas.

On motion of Mr. Heyl, the three subjects above enumerated were referred to the Committee on Science and the Arts for investigation and report.

The Secretary in his monthly report, called attention to a very instructive exhibit illustrating the manufacture of the lately discovered compound known as "Carborundum," now largely employed in the arts as an abrasive material. He also exhibited and commented on a novel metallic flexible tube, devised by Mr. T. R. Almond, of Brooklyn, N. Y.

Adjourned. WM. H. WAHL, *Secretary*.

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THE MANUFACTURE AND DEVELOPMENT OF CARBORUNDUM AT NIAGARA FALLS.*

BY FRANCIS A. FITZGERALD.

The first carborundum furnace consisted of an iron bowl lined with carbon, and a carbon rod; a mixture of clay and carbon was introduced into the bowl and the rod placed in the mixture. A current sufficient to fuse the mixture, or at least to bring it to a very high temperature, was now passed through the furnace, the iron bowl and carbon rod serving as terminals or electrodes. When the current was cut off and the furnace had cooled down, it was opened, with the result that a few bright blue crystals were found surrounding the carbon rod.

The furnaces constructed after this first experiment approached more nearly in form the furnaces in use to-day. They were built of brick, their internal dimensions being

* A lecture delivered before the Franklin Institute, December 11, 1896.

10 inches in length, 4 inches in width and 4 inches in depth. The terminals were a pair of carbons, which could be moved longitudinally, thus permitting the distance between them to be altered at pleasure. These were essentially arc furnaces, that is to say, the idea was to form an arc between the terminals and to bring about the necessary chemical changes by the high temperature thus produced. Mr. Acheson soon found, however, that this method of working was not satisfactory, and he then set about constructing the incandescent furnace, which is the kind that is used to-day.

For this purpose he introduced into his furnaces a core consisting of granulated coke, which formed a continuous electrical connection between the carbon terminals. By adjusting the diameter of the core to the proper size, it was heated to a sufficiently high temperature, by the passage of the current, to convert the surrounding mixture into carborundum.

It was at first supposed that the crystals formed in the furnaces were a compound of aluminum and carbon, but Mr. Acheson soon saw that the amount and quality of the carborundum depended on the amount of silica present in the mixture. A good glass sand was, therefore, substituted for the clay in the mixture. It was also found that the addition of a little salt to the mixture facilitated the running of the furnaces. Some trouble was experienced from the gases formed during the running of a furnace, and to lessen this, sawdust was added to the mixture to render it porous, and allow the free escape of the gas. The output of these small furnaces amounted to about $\frac{1}{4}$ pound a day.

From this time forward the furnaces were gradually increased in size, until, in 1895, furnaces 9 feet long, 1 foot 11 inches wide and 1 foot 9 inches deep, with a core 8 feet long, were employed. The form of the core had also been changed, for while, in 1893, the section was rectangular, it was now circular, and measured about 9 inches in diameter. About 2,000 horse-power hours were expended on a furnace giving an output of about 300 pounds, 1 pound of carborundum thus requiring about 7 horse-power hours for its production.

We may now turn our attention to the works at Niagara Falls. The crude materials for the manufacture of carborundum, viz.: sand, coke, sawdust and salt, are received in the stock building. These are ready for immediate use, with the exception of the coke, which must be reduced to kernels of a certain size to be used as "core" and ground to a fine powder to be used in making the mixture or charge for the furnaces. To effect this, the coke is first passed through a grinder, which breaks it up into small pieces, and is then conveyed to the upper part of the building, where it is passed successively through two cylindrical screens. The first of these removes all particles of coke which are too small to form the core, while the second allows kernels of the requisite size to pass through its meshes and fall into the core bin, conveniently situated as regards the other constituents of the mixture. Below this bin are scales on which the sand, coke, sawdust and salt are weighed out in proper proportions, and then conveyed by an elevator to a mechanical mixer, from which the mixture, ready for use, is emptied into a bin. The arrangement of the machinery connected with all this work is such that it can be attended to with ease by two men.

The furnace room is built to accommodate ten furnaces, though at present there are but five. The furnaces are built of brick, and have the form of an oblong box, the internal dimensions being, approximately, 16 feet in length, 5 feet in width and 5 feet in depth. The ends are built up very solidly with a thickness of about 2 feet. In the center of either end are the terminals, consisting of sixty carbon rods 30 inches long and 3 inches in diameter. The outer ends of the carbons are enclosed in a square iron frame, to which is screwed a stout plate bored with sixty holes corresponding to the ends of the carbons. Through each of these holes is passed a short piece of $\frac{3}{8}$-inch copper rod, fitting tightly in a hole drilled in the carbon. Finally, all the free space between the inside of the plate and the ends of the carbons is tightly packed with graphite. Each plate is provided with four projections, to which the cables conveying the current may be bolted. These ends are the only

permanent parts of the furnace; the remainder, which we shall now consider, is built up every time the furnace is operated.

The side walls of the furnace are first built up to a height of about 4 feet. Pieces of sheet iron are then placed at a distance of about 4 inches from the inner ends of the carbon terminals in such a way as to keep the mixture from coming in contact with the latter. The mixture is then thrown into the furnace until it is rather more than half full. A semi-circular trench having a radius of 10½ inches, and extending from end to end of the furnace, is now formed, the bottom of the trench being a little above the level of the bottom row of carbons. Into this trench is introduced the core, which has been carefully weighed, so that the amount required to make the core of the right size is used. One of the furnaces at Niagara Falls requires about 1,100 pounds of "new core," that is to say, core which has come directly from the bins; or about 850 pounds of "old core," or core which has already been used in the furnace. The reason for this difference in weight will appear later. All the core having been emptied into the trench, the top is rounded off neatly by hand, so that when finished, we have a solid cylinder 21 inches in diameter and about 14 feet long, composed of small pieces of coke and extending from the sheet iron plates at either end of the furnace.

The next operation is to make the connections between the core and the terminals. This is done by packing finely ground coke into the spaces between the ends of the carbons and the pieces of sheet iron, after which the walls are built up to a height of about 5 feet, the pieces of sheet iron removed and more mixture thrown in and heaped up to a height of about 8 feet.

All that is required now to make carborundum is the electric current. The current as supplied from the Niagara Falls Power Company has an electromotive force or pressure of 2,200 volts, so that in order to use it in the furnaces it must be transformed to a lower voltage. This is brought about by a transformer, which, until recently, was the largest in the world, the largest now being that

Jour. Frank. Inst., Vol. CXLIII, February, 1897. (*Fitzgerald.*)

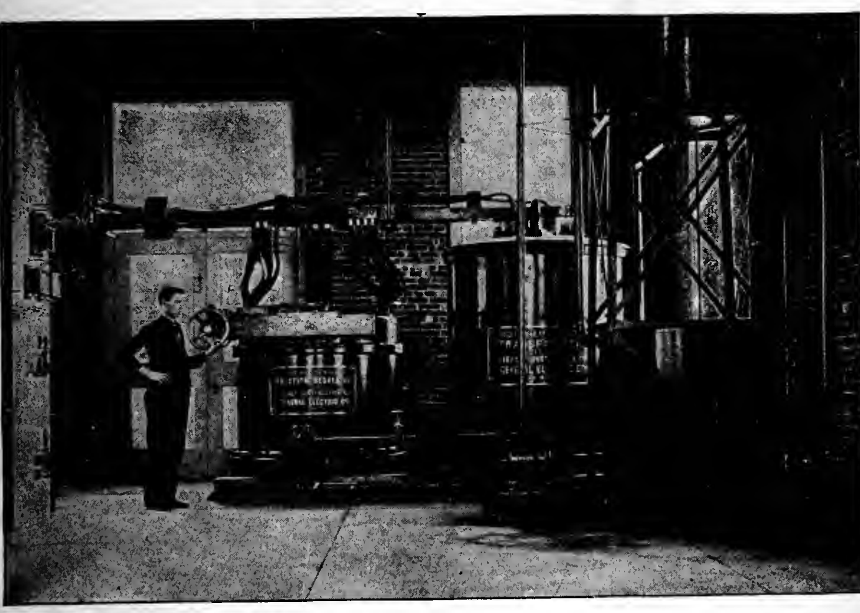

FIG. 1.—Transformer room.

FIG. 2.—Carborundum furnace ready for operation.

used by the Niagara Falls Power Company, in transmitting power to Buffalo. The transformer at the Carborundum Works has a maximum capacity of 830 kilowatts, or about 1,100 horse-power, and transforms the 2,200-volt current into one of only 185 volts. Associated with the transformer is a regulator, by means of which the current from the former can be raised to 250, or lowered to 100 volts.

There is a loss of power in transforming the current to a lower voltage of about 4 per cent., so that with 1,000 horse-power no less than 40 electrical horse-power is transformed into heat. Obviously this would heat up the transformer and regulator to a temperature which would soon destroy them, so that some means must be employed to carry off this heat. Adjacent to the transformer and regulator are two oil tanks, one resting on the floor, and the other directly above and about 8 feet from the floor. The second oil tank contains two coils of pipe, through which water continually flows. A small pump, run by an electric motor, keeps the oil circulating through the regulator, transformer and upper oil tank, the lower one serving as a reservoir for the excess of oil. The oil flowing through the electrical apparatus carries off the heat from them, and is in turn cooled by the water in the coils of pipe. The current from the transformer and regulator is conveyed into the furnace-room by two copper conductors having a sectional area of 8 square inches each. Heavy cables connected with the large main conductors are bolted to the plates of the furnace which is ready for the current. The circuit is completed in the transformer-room by means of a water rheostat. This consists of a circular vessel made of iron, containing salt water, and a large iron plate which can be lowered into the solution. When the circuit is to be closed, the iron plate is lowered into the water until it rests in the bottom of the iron vessel. Similarly, in breaking the current, the plate is lifted off the bottom of the vessel and out of the water. The object of this arrangement is to avoid the dangers which attend other methods of breaking circuits which convey such large currents as that employed in this kind of work.

When the circuit has been completed, readings of the voltmeter and ammeter in the transformer-room are taken. If the furnace has been built with a new core the ampères or volume of the current is at first comparatively small; but if, on the other hand, an old core has been used, the current amounts to about 1,200 ampères. The reason of this is that the old core, having been already used in a furnace, has been heated to such a high temperature that all impurities have been driven off, and it, consequently, is a much better conductor than the new core. By means of the regulator the electromotive force or pressure of the current is now raised so as to overcome the resistance of the core, which is always comparatively great at first, even in the case of an old core, since, when carbon is cold, its resistance is much greater than when hot. In the case of a furnace having an old core, the resistance diminishes very rapidly, and at the end of about an hour the volume of the current has increased to the point where 746 kilowatts or 1,000 horse-power is being expended in heating the furnace. As the volume of the current continues to increase, the regulator is run back, reducing the electromotive force. Finally, the resistance of the core becomes constant, and very little more regulation is required. The phenomena attending the operation of a furnace containing new core are similar, but it takes a longer time for the resistance of the core to become sufficiently low to allow a 1,000 horse-power to be employed.

Readings of the voltmeter and ammeter are taken every quarter of an hour during the run of the furnace. From these the kilowatts are calculated and plotted on the power curve. From the area of the curve the total power used is calculated.

After the circuit has been closed in the transformer-room, no apparent change occurs in the furnace for about half an hour. Then a peculiar odor is perceived, due to escaping gases, and when a lighted match is held near the furnace walls the gas ignites with a slight explosion. When the current has been on for three or four hours, the side walls and top of the furnace are completely en-

veloped by the lambent blue flame of carbon monoxide gas, formed by the combination of the carbon of the coke with the oxygen of the sand. During the run of a single furnace 5½ tons of this gas are given off. At the end of four or five hours the top of the furnace begins to subside gradually, fissures form along the surface, from which pour out the yellow vapors of sodium. Occasionally, the mixture on the top of the furnace is not sufficiently porous to allow the rapid escape of the gases. The result is, that the latter accumulate until the pressure is so great that, at some weak point in the mixture above, a path is forced open and the gases rush out violently. This is termed "blowing" by the workmen, and the phenomena accom-

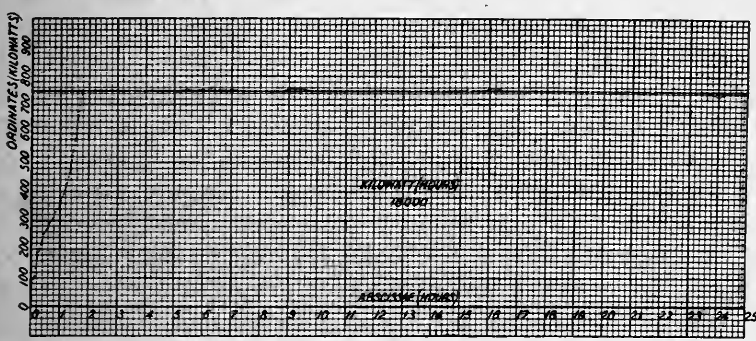

FIG. 3.—Power curve.

panying it are frequently as follows: A fissure suddenly forms at some point in the top of the furnace, and from this burning gases rush out with a loud, roaring sound. A miniature crater rapidly forms, from which white, hot cinders are thrown to a height of several feet, the issuing gases meanwhile burning with a dazzling yellow flame, dense white vapors soon filling the whole furnace room. In a bad case of this kind it is necessary to cut off the current from the furnaces and allow the latter to cool down somewhat. Then the mixture surrounding the crater is dug out to a depth of about 2 feet, exposing the "blow hole," which is removed, and the cavity formed filled up with fresh mixture. It is mainly for the purpose of avoiding this "blow-

ing" that the sawdust is put in the mixture, since the former, by making the mixture porous, allows the gases to escape freely.

At the end of about twenty-four hours the current is cut off from the furnace and it is allowed to cool for a few hours. Then the side walls are taken down and the unchanged mixture raked off the top of the furnace, until the outer crust of amorphous carborundum is reached. This crust is cut through with large steel bars, and can then be easily removed from the inner crust of amorphous carborundum. The inner crust is next removed with a spade and the crystalline carborundum exposed.

A cross-section of a carborundum furnace presents an interesting and beautiful appearance. In the center is the core, which, on examination, is found to be very different in some of its physical characteristics from the coke of which it was originally composed. It no longer possesses a bright metallic appearance. Many of the kernels are quite soft, and can be squeezed between the fingers, leaving on them a mark like black lead. In fact, the high temperature to which the core has been raised has driven off all impurities from the coke, leaving nothing but pure carbon, either in the amorphous or graphitic form. From the core radiate beautifully-colored carborundum crystals to a distance of 10 or 12 inches. A single furnace yields over 4,000 pounds of crystalline carborundum. Most of these crystals are not remarkable as regards their size, but in places where hollows have formed, large hexagonal crystals are found, sometimes measuring ½ inch on a side. At the distance of 10 or 12 inches from the core the crystals suddenly cease, and instead, we find a thin layer of a light-green color, which is the inner crust of amorphous carborundum. Beyond this is the outer crust of amorphous carborundum, and this also ends abruptly in unchanged mixture. Other curious substances are sometimes produced in the furnaces; for example, silica, which has the appearance of spun glass. But, perhaps, the most interesting substance that is sometimes found is a curious layer next the core, of what Mr. Acheson has aptly termed the "car-

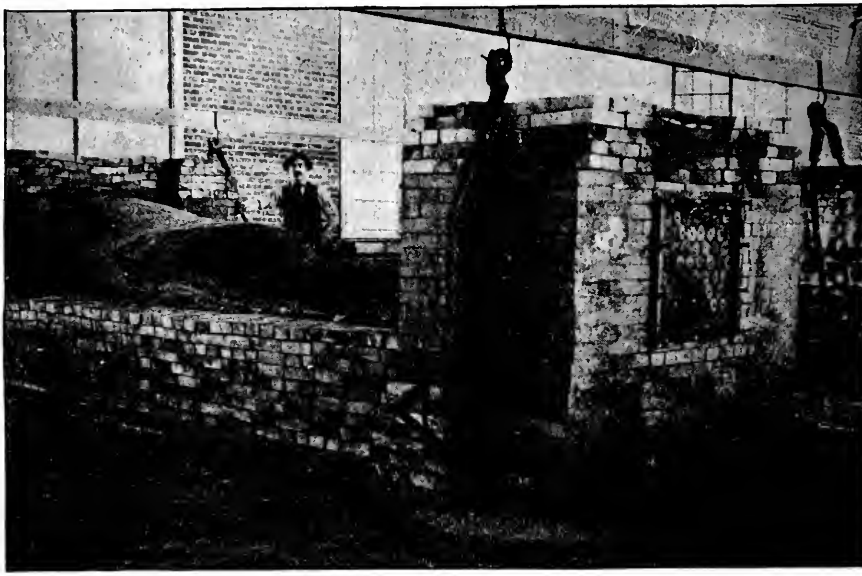

FIG. 4.—Furnace opened to show formation of carborundum around the core.

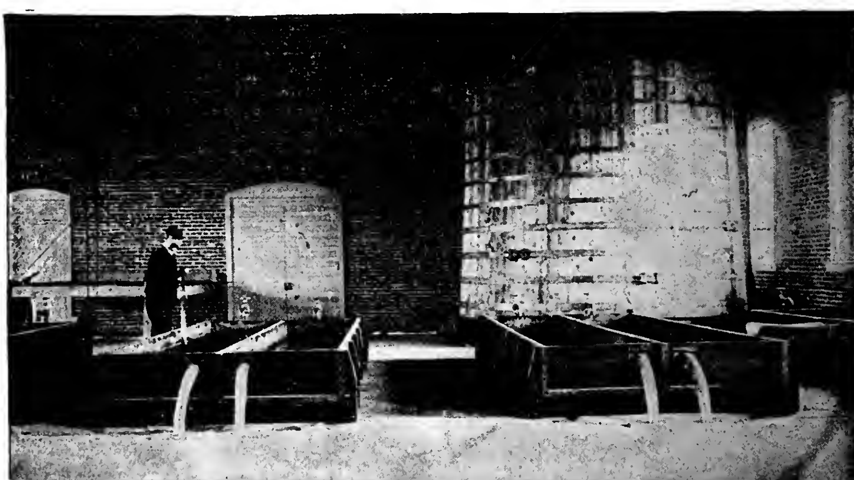

FIG. 5.—Cleaning the crude carborundum in the acid tanks.

FIG. 6.—1,500-ton press used in making vitrified wheels.

FIG. 7.—View of interior of kiln for vitrifying wheels.

bon skeleton of carborundum." On opening a furnace and cutting down to the core, a layer is found that appears at first sight to consist of very dull black carborundum crystals. On closer examination, however, it is found that though this material has the exact form of the carborundum crystals, it is nothing but pure carbon in the graphitic form.

This formation of the graphite skeleton of carborundum is interesting from another point of view, in that it suggests a new explanation of the formation of graphite from amorphous carbon. It has generally been supposed that when amorphous carbon is subjected to a very high temperature, like that of the electric arc, it is converted into graphite. Mr. Acheson, however, has pointed out that this does not properly explain what occurs; but that before the graphite has been formed, the carbon has entered into chemical combination with some other element, and that the compound thus produced is then decomposed, leaving behind carbon in the graphitic form. Attention has been called to the fact that after the furnace has been run, the core consists of pure carbon, either of the amorphous or graphitic form. Now if the production of graphite were simply a question of temperature, we might expect to see the whole core converted into graphite, instead of only part, that part being changed because of the presence of impurities in the coke, which have formed with the carbon chemical compounds, afterwards decomposed. It may be said that the whole core would be turned into graphite if heated to a high temperature for a sufficient time. This, however, is not the case, for even when the same core has been used in several furnaces, there is no appreciable increase in the amount of graphite formed after the first run.

At first sight it may seem strange that, so far as we know, carborundum does not occur in nature, even to a very small extent. Probably the explanation of this lies in the fact that the temperatures of formation and decomposition lie very close together. Other things equal, the temperature of the core in a carborundum furnace depends on the area of the cross-section, and since, in a given furnace, the

length of the core is constant, the increase or diminution of the weight of core used will cause a corresponding increase or diminution in the area of the cross-section. If a core 3½ per cent. less than the normal weight is used, it obviously makes a comparatively small difference in the sectional area and consequently in the temperature, yet this difference is sufficient to cause the decomposition of a large amount of carborundum next the core, the silicon being driven off in vapor and the graphite skeleton left behind. In a similar way a comparatively small increase in the amount of core used will decrease the amount of carborundum produced.

After the carborundum has been removed from the furnace it is taken to a crusher, which consists of a large iron pan, rotated in a horizontal plane by means of a vertical shaft. A horizontal shaft, carrying two heavy rollers, is attached to a collar surrounding the vertical shaft, thus permitting a free vertical motion of the rollers which rest in the pan. The latter, in revolving, causes the carborundum to pass under the rolls, which break the mass of crystals apart. From the crusher the carborundum is taken to large wooden tanks, where it is treated for several days with dilute sulphuric acid to remove impurities. It is then thoroughly washed, dried and graded. There are twenty grades of crystals, from No. 8. to No. 220, the numbers indicating the meshes to the linear inch of the screen through which the crystals have passed. The washings from the crystals pass through a series of tanks which serve to collect the fine powders, and from these are made the so-called "flours" and the hand-washed powders. The former are obtained by floating the ungraded powders in a stream of water flowing through a series of tanks, in which the powder settles. There are three grades of "flour," designated according to their fineness, F, FF and FFF. The hand-washed powders are obtained by stirring up a quantity of ungraded powder with water, allowing this to settle for a definite time—6 minutes, for example—and then pouring off of the supernatant liquid. The powder, which afterwards settles from this liquid is called 6-minute powder. In a similar way other hand-washed powders are made, 1-, 4-, 10- and 15-minute powders.

Having now followed the manufacture of carborundum from the preparation of the crude material for the mixture to the production of grains and powders in a commercial form, it may be of interest to consider its properties and uses.

Carborundum is apparently infusible; for after a certain temperature has been reached, decomposition commences, without fusion, and the crystals are broken up into carbon and silicon. It is quite insoluble in water or any acid. Its hardness lies somewhere between 9° and 10°, probably very close to 10°, which is the hardness of diamond. An attempt was made to obtain some idea of the relative hardness of diamond, corundum and carborundum by the following experiment:

A series of lines was scratched on a small plate of glass with each of the three materials, and the scratches examined with a microscope. The appearance of the lines made by the diamond and the carborundum crystal was indistinguishable; but that made with the piece of corundum was quite different, being rough, and not presenting the clean-cut outlines of the other scratches. This seems to show that carborundum is much nearer diamond than corundum in hardness, although it is not as tough. The specific gravity of carborundum is 3·23, which is less than that of emery, 1¼ pounds of the latter being equal in volume to 1 pound of the former. This is important for two reasons:

(1) It makes the relative cost of carborundum less than it appears at first sight; and

(2) A carborundum wheel is considerably lighter than an emery wheel of the same dimensions, which, of course, is a distinct advantage.

The most interesting application of carborundum as an abrasive is in the form of wheels. Taking what may be described as simple wheels, that is, those which are nothing more than circular discs having a hole in the center, the number which may be called for is very large. In the list of wheels given in the Carborundum Company's catalogue, we find that the diameters vary from 1 inch to 36 inches, the thicknesses from ¼ inch to 4 inches, the grits or sizes of

the crystals are more than twenty in number, and the grade scale, which is constructed to give the different degrees of hardness of the binding material contained in the wheels, consists of nineteen points. With these data a very conservative estimate of the number of different wheels which may be called for gives 80,000. Besides this there is an enormous number of dental wheels and wheels of special shapes, such as cylinders, cup wheels, roll-grinding wheels, special wheels for grinding machinery, saw-gummers, moulding wheels, etc. Besides the wheels there are many other forms in which carborundum is used, such as sticks, knife-sharpeners, hones, sharpening stones, gouge stones, slips, scythe stones, axe stones, cloth, paper, etc.

In the greater part of carborundum goods put on the market the vitrified bond is used. In making wheels or other goods in this way, the carborundum is mixed in certain proportions with kaolin and feldspar, and the mixture is then placed in a mould and pressed in a hydraulic press. The wheel, when removed from the mould, is placed on a support called a "bat," which is made of baked clay. The vitrification of the wheels is carried out in kilns similar to those used in making porcelain. The bats on which the wheels rest are placed in clay saggers, and then built up in columns until they reach the roof of the kiln. When the kiln is filled it is closed and fired, an operation occupying about seven days, and is then allowed to cool slowly. When the wheels are removed they have to be placed in lathes, trued up with dressers, or diamonds, and the hole bushed to the proper size. It is not easy to realize, at first, what a remarkable piece of work a carborundum wheel is. Who, looking at one of these wheels, measuring 36 inches in diameter and 4 inches in thickness, would think that the cutting material is produced by an expenditure of energy amounting to 1,250 horse-power hours?

Another bond, which has lately been employed with carborundum, is shellac. This is not of such wide application as the vitrified bond, but for work requiring very thin wheels or special forms, it gives very satisfactory results.

One of the first questions asked by a person who is alto-

gether unfamiliar with carborundum, is: "How much cheaper is carborundum than emery?" On being told that it is not cheaper, but from two to five times dearer than emery, he wishes to know why people should buy it under such circumstances. There are three reasons for this:

(1) As compared with emery, carborundum does more work:

(2) It does faster work:

(3) It does better work.

Another question often asked is, whether actual tests have been made for the specified purpose of comparing the relative value of carborundum and emery as abrasives. Such tests have been made, but they are very unsatisfactory. To make a really satisfactory test of this kind, it would be necessary to use a great many wheels of carborundum and emery, to make careful notes of the work done, the rate of doing work, and the finish of the work, and, from examination and comparison of these, to draw conclusions. Although no such test as this has actually been undertaken for the purpose of comparing carborundum and emery, yet data have been obtained under circumstances which fill all the requirements of a regular test. Among the large users of abrasives very careful observations are made of the amount of work, rate of work, and quality of work done by their emery, corundum or carborundum wheels, as the case may be. The results obtained from such observations as these are of far greater value than anything that could be done in the way of special tests. In the case of the latter there would always be subject for doubt as to whether the tests were carried out under proper working conditions. With the user of abrasives, however, there can be no doubt of this sort. He has been using emery or corundum for years, and finally he gets a carborundum wheel, which he tries, having before him the fact that it is far more expensive than an emery wheel, so we may feel perfectly sure that unless the superiority of carborundum is very decided, he will not waste time or money in making further experiments. A few of the results of observations made by men thoroughly experienced in the use of abrasives will then be of

interest, as giving us data from which we draw conclusions as to the relative values of carborundum and emery as abrasives.

Watchmakers have found that carborundum may be used in place of diamond, as it does the work equally well, and, of course, is much cheaper. Emery and corundum are quite unsuitable for this class of work.

In finishing the soles of shoes, garnet or emery, mounted on cloth or paper, is used. Numerous tests have been made by shoe manufacturers on the use of carborundum in this work, and they state that it does, approximately, six times the work of emery or garnet, does the work faster and puts on a better finish.

Extensive experiments have been made by a well-known plate-glass manufacturer, to find out whether carborundum can be used in that industry. In this manufacture the plate glass must be ground and polished. For this purpose a large mass of iron, weighing as much as half a ton, is passed over the plate of glass and grinds the surface, sand being used as the abrasive material. After the glass has been treated sufficiently with the sand, emery is used in its place, the final polishing being done with rouge. It requires about 20 tons of new sand to finish 1,000 square feet of glass. The experiments with carborundum show that 750 pounds of that material will do the work of about 20 tons of sand, and that ½ a pound of carborundum will do the work of 12 pounds of emery. The experiments, however, were not entirely successful, for though a very small amount of carborundum was required to do the work, its extreme hardness made scratches on the glass plate. It is hoped, however, that this difficulty may be overcome.

In the manufacture of pottery and porcelain, blocks of carborundum are used for smoothing up the "biscuit ware," emery and corundum blocks having proved very unsatisfactory for this purpose.

In the manufacture of bath-tubs, rubbing blocks of emery have been used. In this class of work it is found that a man can do as much work with a carborundum block in one hour, as he could do with an emery block in one day.

Roll grinders record some very interesting observations of the work done by carborundum wheels. Thus it was found by one firm that emery wheels would grind about 65 rolls each before wearing down so much as to be useless; while carborundum wheels would grind 220 rolls each. Another roll grinder, who purchased a carborundum wheel, stated, when it ground 14 rolls, that it had "already beaten emery." When he next reported, he stated that the same wheel had ground 128 rolls, and was "good for 5 or 6 more." The difference in the number of rolls ground in these cases was due to the difference in their size.

An order was sent from a certain well-known car-wheel works for a carborundum wheel 18 inches in diameter and 2½ inches thick. A wheel of this size costs $15.38, while an emery wheel of the same size would cost $7.15. The agreement in this case, however, was that the Carborundum Company should receive 2 cents for every car-wheel ground. In order, then, to get the proper price for the wheel, it would have to grind 769 car-wheels. As a matter of fact, it ground 1,201, so $24.02 was paid for it.

Many more results obtained from carborundum wheels might be given, but those already mentioned are sufficient to show that these wheels are far superior to emery or corundum.

It is probable that, before long, a new field of usefulness will be opened to carborundum. In 1893, Dr. Wm. H. Wahl suggested to Mr. Acheson that carborundum might be used as a substitute for ferro-silicon. Since that time, however, Mr. Acheson has been too much occupied with the development of carborundum in the abrasive trade to make any experiments in the direction suggested by Dr. Wahl. It might have been expected, however, that before long this use for carborundum, so quickly recognized by Dr. Wahl, would be taken up by workers in the metallurgy of steel and iron. And such is the case, for experiments have been made with carborundum, not only by the metallurgists in the United States, but by those in England and Germany, with very promising results. The subject has been thoroughly treated by Mr. F. Luermann, of Germany, who finds that carbo-

rundum is soluble in molten steel, and suggests its use as a source of silicon in the manufacture of that material, if it can be obtained at a sufficiently low price. He estimates that carborundum which would be used in this way, in Germany alone, would amount to 2,444 tons a year.

Since Mr. Acheson discovered carborundum, in 1891, there has been other interesting work done on somewhat similar lines, notably that by Prof. Henri Moissan, of France, though, as yet, none of it has resulted in the formation of a new industry, like the manufacture of carborundum. However, in the future we may expect to see other wonderful results obtained from the electric furnace, in which temperatures can be reached that probably do not fall far short of that of the sun itself.

THE CYANIDE PROCESS FOR THE TREATMENT OF GOLD ORES.*

BY JOSEPH W. RICHARDS, PH.D., Member of the Institute.

Just three weeks ago to-day the news was flashed under the Atlantic Ocean that the High Court of the Transvaal had given a decision against the African Gold Recovery Company in its suit to compel payment of royalties for the use of the cyanide process, and had thus invalidated the MacArthur-Forrest patents in the Transvaal. This event was the sequel to a very interesting chapter in the history of gold mining.

In 1889, Herr Adolph Goerz, a well-known mining engineer, said, in the leading mining journal of Germany, that 50 per cent. of the gold mined in the Transvaal was going to waste. The common practice at that time was to crush and amalgamate the ore, the tailings from the amalgamation pans being in some cases concentrated, and the heavy concentrates treated by the Plattner chlorination process. It was a fact, then, and is true even to-day, that about 50 per

* A lecture delivered before the Franklin Institute, November 27, 1896.

cent. of the gold in the Transvaal ore is obtainable by amalgamation, 5 to 10 per cent. by chlorination of the concentrates, while 40 per cent. goes into the tailings from the concentrators. The difference between 1889 and 1896 is this: that whereas then no process was known for treating the tailings economically, and they were thrown away, now 90 per cent. of the gold in them is extracted by the cyanide process, at a handsome profit. Of the $40,000,000 return of gold from South Africa last year, at least $10,000,000 was won from tailings by the cyanide process, at a cost of (approximately) $5,000,000, leaving a clear gain to the gold interests of $5,000,000.

A process which, in five years after its introduction, can save to one country alone $5,000,000 a year, is certainly worthy of the respectful consideration, not only of the scientific world, but also of all who are interested in the progress of the industries.

The cyanide process is based on the fact that metallic gold is soluble in solutions of potassium cyanide. It is, indeed, a curious fact that *metallum rex*, which resists the attack of the strongest acids, only succumbing to that powerful mixture, *aqua regia*, should be quietly though energetically dissolved by an alkaline solution of a simple salt—potassium or sodium cyanide; yet the fact has been known since the beginning of the century.

(Experiment: Some gold leaf was floated on the surface of a solution of potassium cyanide in a watch-glass, when it was rapidly dissolved.)

On March 25, 1840, G. R. & H. Elkington, of Birmingham, England, patented the process of electrically depositing gold from its solution in potassium cyanide, using a gold anode to regenerate the solution. This is the process used even now to gild electrolytically, and the credit of its invention is said to be due to Dr. Wright, of Birmingham, for whom the process was patented by the Elkington Brothers.

The first scientist to study critically the conditions affecting the solubility of gold in cyanide solutions was Prince Pierre Bagration (*Bulletin de l'Academie Imperiale des Sciences de St. Petersburg*, 1843, t. 11, p. 136). He found that the gold

dissolved more quickly in a warmed solution, and that solutions of ferro-cyanides also dissolved gold, but not so energetically as the simple cyanides. He noticed also that the action of air facilitated the process of solution.

(Experiment: A fragment of gold leaf was placed in each of two vessels containing a 1 per cent. solution of potassium cyanide. Air was allowed to bubble through one, while the other was kept in agitation by stirring with a glass rod. In fifteen minutes the leaf in the first was entirely dissolved, while the other was apparently unattacked.)

L. Elsner (*Jahrbuch für Chemie*, 1844, p. 441) studied the question more closely, found that gold would not decompose cyanide solution without the presence of oxygen in some other form than as water, and that the reaction is:

$$2Au + 4KCy + O + H_2O = 2(AuCy.KCy) + 2KOH.$$

Theoretically, 1 part of potassium cyanide should dissolve $1\frac{1}{2}$ parts of gold, requiring $\frac{1}{25}$ part of oxygen.

The idea of making use of this solubility of gold in cyanide solution for the extraction of gold from its ores is said to have originated with Alexander Parkes and Dr. John Wright, who, in 1848, applied for a patent containing the following passages. (I quote from the *Engineering and Mining Journal* of December 16, 1895.)

The invention consists in separating gold or silver from their ores by means of cyanide of potassium, sodium or ammonium. * * * In order to facilitate the operation, the ore should be in a fine state of division. To every ton of ore, one-fourth to one-half of its weight of a 3 to 6 per cent. solution of potassium cyanide is used, heated in a suitable vessel to 150°–180° F. for one to three days. The solution is then filtered off, evaporated to dryness, and the residue fused in a crucible, by which the gold is collected to a button and the cyanide regained. The specifications conclude with: "I do not confine myself to the proportions above given, as more or less of the solvent must be used, according to the earthy or other impurities, nor do I confine myself to the above method of obtaining the gold from the solution."

This specification certainly contains the idea of the cyanide process, but there seems to be a doubt as to the genuineness of the reference. The *Engineering and Mining Journal* does not state the number of the patent; and while it is true that Parkes and Wright did take out patents in 1848, an examination of the full text of their patents from 1840 to 1860 has not revealed to me the above quotation, or anything approximating to it. I do not say that the patent may not have been applied for, but simply that I have not been able to find it by a diligent search.

At any rate, Parkes' proposed method never had any commercial application, and in the light of our present knowledge we can easily see why. (1) Too much cyanide would be lost by using so strong a solution, and keeping it hot one to three days. (2) The after treatment of the filtered liquid would be expensive and wasteful. The gold platers soon found out that metallic zinc precipitated gold from its cyanide solution in their plating baths, and the proper application of this observation was one of the necessities for rendering the cyanide process economical.

Subsequent patents were obtained as follows:

J. H. Rea, of Syracuse, N. Y. (U. S. P. 61,866, February 5, 1867). Use of potassium cyanide solution to dissolve the gold from the ore, and an electric current to decompose the solution and precipitate the gold.

Thomas C. Clark, of Oakland, Cal. (U. S. P. 229,586, July 6, 1880). The ore is roasted, and while red-hot dropped into a solution of common salt, ferro-cyanide of potassium and caustic soda, as a preparation to amalgamation.

Hiram W. Faucett, of St. Louis, Mo. (U. S. P. 236,424, January 11, 1881). The red-hot, roasted ore is dropped into a solution containing common salt, potassium nitrate, sodium cyanide, ferrous sulphate and copper sulphate. This also is intended merely as a preliminary to amalgamation, to dissolve any coating from the gold, and render it more susceptible to amalgamation.

John F. Sanders, of Ogden, Utah (U. S. P. 244,080, July 12, 1881). A solution of potassium cyanide and phosphoric acid is used in connection with amalgamation, to dissolve

the coating from the gold. This inventor plainly declares: "I am aware that cyanides have already been used in the extraction of gold."

J. W. Simpson, of Newark, N. J. (U. S. P. 323,222, July 28, 1885). The ore is powdered, agitated with solution of potassium cyanide and a little ammonium carbonate, filtered, a plate of zinc suspended in the solution to precipitate the gold, either scraping off the precipitated metal or dissolving away the excess of zinc by acid. The inventor declared he was aware that cyanide of potassium had been used, in connection with an electric current, for dissolving gold, and that zinc had been employed as a precipitant.

Regarding the last statement, it was known, as far back as 1851, that zinc would precipitate gold from solutions of gold in potassium cyanide, it being recommended as one of the agents by which gold could be precipitated from such solutions, and thrown down upon any article to be gilded, by the single-plate battery process.

None of the above-mentioned attempts were practically successful, while the process as exploited by the next following inventors was successful from the first.

The Cassel Gold Extraction Company was started in England in 1885, with a paid-up capital of $600,000, to operate some patented gold processes. These proving worthless, it purchased, in 1887, the cyanide process patents of MacArthur and Forrest. In 1889, its capital was increased to $750,000, all paid in; and in 1892 to $1,200,000, when the company began to pay dividends. The American patents were sold to the American Gold and Silver Extraction Company, of Denver, for $2,000,000 in shares; the South African patents to the African Gold Recovery Company for $100,000 in cash and $325,000 in shares; the Australian patents to the Australian Gold Recovery Company for $100,000 in cash and $265,000 in shares. After that, patent rights were sold in Mexico and other countries for cash and shares, and the parent company paid large dividends. The American Company has never collected much revenue, but the others mentioned have received large sums in royalties, probably between $1,000,000 and $2,000,000 having

been paid for the use of the process in the Transvaal alone. The process was first worked in 1888, at Ravenswood, in Australia; in 1889, at Barberton, and soon afterwards was introduced at Johannesburg.

Such being, in brief, the story of the phenomenal rise of the commercial cyanide process, connected almost exclusively with the names of MacArthur and the Forrest Brothers, of Glasgow, let us examine the actual patented basis on which their success rested. Their English patent, of August 10, 1888, specifies as follows: "The ore is powdered, treated with a very dilute solution of a cyanide salt, such dilute solution having a *selective action* such as to dissolve gold or silver in preference to the baser metals. The process is expedited by stirring the mixture of ore and solution. The solution is drawn off and treated in any known way, as with zinc, for recovering the gold and silver. For ordinary ores is used one-half their weight of a solution containing 0·2 to 0·8 per cent. cyanogen" (0·5 to 2 per cent. potassium cyanide).

In this patent the idea of novelty was based entirely on the use of the *very dilute* solution, as having a selective action and dissolving out the precious metals first. If exposure of the ore to 50 per cent. of its weight of such solution did not extract the gold satisfactorily, the solution was not made stronger (as that would entail greater loss of cyanide by dissolving the other metals present), but more of the solution was used.

This patent was supplemented by another one, claiming the use of zinc sponge or turnings in a box of special construction, forming a metallurgical filter (United States Patent 418,138, December 24, 1889), which has come into general use and will be described in detail further on. A companion patent (No. 418,137, December 24, 1889) describes the preliminary washing of the ore with an alkaline solution before subjecting it to the cyanide solution.

We have now examined the patented basis of the MacArthur-Forrest process, and the essential details may be summarized as:

(1) Use of a *very dilute* solution of cyanide.

(2) Precipitation by *spongy* or *thread-like* zinc.

(3) Preliminary alkaline wash, if necessary.

One is almost inclined to ask: "Is that all?" and I will reply that it is not. MacArthur and Forrest attacked the problem in a truly scientific manner. Not satisfied with some rule-of-thumb, hit-or-miss method of procedure, they investigated carefully, as chemists, every step in the series of operations involved. They subjected numerous ores to test, and, by making elaborate chemical analyses, determined exactly what constituents were detrimental to the cyanide solution, how their effects could be counteracted, and how, if possible, the impurities could be completely removed. They determined carefully the length of time required, the strength, and the amount of solution necessary and most economical for the treatment of various ores. They did not, of course, bring the process to perfection, but they put it on a solid basis of experimentally verified facts, and to this I, as a believer in scientific methods, ascribe the well-earned success which they have achieved.

It will now be interesting to turn our attention to a large-sized cyanide plant in full operation, and to describe the process as it is at present practised.

At the Metallic Extraction Company's works, at Florence, Col., the plant, at the beginning of 1896, handled 100 tons of rock per day, carrying $14 worth of gold per ton. The ore is broken first to walnut size, then to pea size, and finally ground to dust. It is then transferred to leaching tanks, 30 feet in diameter and 3 feet deep, each capable of holding 100 tons of dust. These tanks are of steel, having wooden bottoms, the latter being made double, as described in what follows: Strips of wood, 1 inch thick by 3 inches wide, are set up on edge promiscuously on the bottom of the tank, while a circular strip 3 inches high is fastened entirely around the bottom, 1 inch from the sides. The space between the strips is then filled with small pebbles to the level of the top of the strips. Over the whole is placed a circular piece of duck, cut about 6 inches larger in diameter than the tank. The canvas is pressed down into the 1-inch space between the circular ridge and the side of the

tank, a piece of 1-inch rope being pressed into this space to keep it down tight. The canvas is ordinary 10-ounce cotton duck, stitched like a sail. In the bottom of the tank, and closed by a valve, there is an outlet for solution.

The bottom having been arranged as above described, the vat is then filled with the ground ore, and 50 tons of 0·3 per cent. potassium cyanide solution is run in, just covering the surface of the ore. This remains one to three days, and is then drained off. The tank is then filled with a 0·1 per cent. solution, which is allowed to remain one day and is then also drained off. This is sometimes followed by a wash of 10 to 20 tons of pure water. The ore after this leaching contains 30 cents to 50 cents per ton.

The solution is run through four zinc boxes, each 18 feet long, 4 feet wide and 2 feet deep, and divided into ten compartments. Each compartment contains about 50 pounds of zinc turnings, and the box will precipitate the gold from the solution as fast as a 2-inch pipe will drain the vats, but it is not advisable to run it through more quickly than at one-fourth of that rate, lest the current should carry along with it, out of the precipitating tank, the finely divided gold.

During solution and precipitation, the loss of cyanide is approximately 1 pound per ton of ore treated, which costs 50 cents per pound.

The zinc boxes are cleaned up once a month. The turnings are vigorously shaken, to loosen the adherence of the fine gold, and the solution in the bottom of the tank is flushed out with the gold onto a canvas filter. The coarse particles of zinc are picked out and returned to the boxes; the gold slime is transferred to a lead-lined tank provided with a hood and is treated with sulphuric acid to dissolve out the zinc. If the slimes are well treated, the zinc is almost entirely removed, and the residue will contain over 50 per cent. of gold; if carelessly treated, they may contain 30 per cent. of zinc. After being washed and dried, they are melted down in crucibles with borax and soda, silica sand being added if zinc is present in any quantity. The bullion thus obtained is 800–950 fine. The cost of the process in the Transvaal may be summarized as follows:

	Per Ton of Ore.
Labor	$0.50
Potassium cyanide	.40
Zinc	.20
Coal, chemicals	.10
	$1.20

In Colorado, the cost of crushing and freight charges bring the total cost to from $3 to $5 per ton, making it profitable to treat ores carrying ½ ounce of gold or over. The Florence Works has been enlarged this year to four times its former capacity.

In South Africa three kinds of material are available for the cyanide treatment:

(1) Old tailings, the pyrites fully oxidized and washed out by the rains. They contain no acid, salts or slimes, and present no difficulties at all in the process.

(2) Recent tailings, partly decomposed, rich in ferrous and ferric salts and sulphuric acid. These present difficulties which are not insurmountable.

(3) Quite fresh tailings, entirely undecomposed. These are not yet perfectly treated, and need improvement in their handling.

At the Robinson Mine, the ore is first crushed and amalgamated; the tailings are put over Frue vanners, which separate them into concentrates and residues. The former are treated by chlorination, the latter are separated by "*spitz kasten*" into slimes and sands. The former are run away, the latter are put through the cyanide process. Practically, the only difference between the cyanide process at this works and that previously described, is that the precipitated gold from the zinc boxes is first roasted one or two hours at a dull-red heat, to oxidize the zinc and other base metals, and then melted down with borax and soda to bullion 600 to 800 fine.

Later improvements in the Transvaal have been directed towards doing away entirely with the chlorination process, and the saving of the slimes. The amalgamation residues are separated into four different grades by washing, and the cyanide process applied to each in a different manner, using

different strengths of solutions and different times of exposure. The slimes are mixed with lime, to render them more porous, and then leached. On these lines the extraction from the amalgamation residues has reached 90 per cent.

In the United States there are no large banks of tailings on hand to work, and the cyanide process has been applied simply to those ores to which it was best suited. These are particularly:

(1) The porous limestones of the Camp Floyd district, Utah. In these the gold is so very finely divided that no show of *color* can be obtained by washing in the miner's pan, and only about one-fourth of the gold can be extracted by amalgamation. The ore was practically unworkable by previous processes; but, from its porous, easy-leaching qualities and the fine state of division of the gold, it was the ideal ore for cyanide treatment, so that, to quote a recent expert report, "every mine, with reasonable ore bodies opened, equipped with a cyaniding plant, is a dividend payer." This ore needs only to be broken to about ½-inch lumps to be ready for treatment, about 85 per cent. of its gold being extracted at a total cost of $2 per ton. Five mills are already treating over 200 tons of ore per day, and three or four more are in process of erection. The cyanide process has literally created this mining district, and rendered workable one of the largest deposits of gold ore in America, a field having an area of 80 square miles and an average thickness of ore bed of 40 feet.

(2) The telluride ores of the Cripple Creek district. As is well known, these ores are very unsatisfactory for amalgamating, while roasting before amalgamation hardly mends matters. The cyanide process has been found very suitable for some classes of these telluride ores, and at Florence, Cripple Creek, and several other localities, is in successful operation. However, there are some kinds of Cripple Creek ore which do not work very satisfactorily, possibly because of selenium, but the exact reason is not yet quite clear. There are still unsolved problems for the cyanide process to conquer, and in solving which the chemist will find occupation for his highest skill.

Ores containing much copper usually consume large quantities of cyanide by the formation of copper cyanide, and are, therefore, unsuitable for the process. One per cent. of copper is the maximum which can usually be worked. Ores containing much lead sulphide, zinc sulphide or unoxidized iron pyrites, sometimes work satisfactorily and at other times not, the exact conditions for success having to be determined independently for each ore by careful experimenting; in some cases the ore cannot be worked at all by this process.

As just described, the cyanide process has been in use several years, with the result that others besides MacArthur and Forrest have devised improvements in its operation. The points on which improvement was most needed were:

(1) Increased speed of solution.

(2) Lower consumption of cyanide.

(3) A better method of precipitation than by zinc.

The mine owner would certainly have added to these a fourth very desirable improvement, viz.: freedom from paying the large royalties required, amounting to from 6 to 10 per cent. of the net output. This, as I mentioned in commencing, has been abrogated in the Transvaal.

Many inventors have attempted to increase the rate of solution of the gold by adding various chemicals to the solution. Molbenhaur uses ferrocyanide of potassium; Schering, potassium persulphate; Dupré, chromic acid; Mactear, hypochlorites; Crawford, cyanates; Peleton and Clerici, hydrogen peroxide and potassium permanganate; Kendall, sodium peroxide.

The principle of all these additions is to furnish the oxygen required for the reaction in a more available form than atmospheric oxygen. The only one of these that I can find proof of being in extensive use is Kendall's. About half a dozen plants in the West are using it, finding, on their particular ores, that solution can be hastened about 50 per cent., and thus the consumption of cyanide notably decreased. The reactions involved will serve as a type of most of the other methods, viz.:

$$Na_2O_2 + H_2O = 2NaOH + O;$$

therefore,

$$2Au + 4KCy + Na_2O_2 + 2H_2O = 2(AuCy \cdot KCy) + 2KOH + 2NaOH.$$

For lessening the consumption of cyanide, two expedients are resorted to:

(1) A preliminary treatment of the ore.

(2) The use of more dilute solutions.

It has become a settled practice to leach the ore first with pure water, if it should contain more than traces of soluble sulphates. However, some basic sulphates of iron insoluble in water can react on cyanide, so that if these are present, the preliminary wash is made with solution of caustic soda, or the ore is mixed with lime and leached. Sometimes careful roasting will decompose the soluble sulphates, forming oxides, and so rendering them harmless. The use of more and more dilute solutions has been the tendency in the Transvaal, where 0·05 per cent. solutions are considered fairly strong, and solutions as dilute as 0·01 per cent. are used. With this dilution, more of the solution is used to treat a ton of ore, say 1½ to 2 tons of solution, and less cyanide is lost than when using stronger solutions.

The use of more dilute solutions has emphasized the need of a better precipitant than zinc. When the latter is used, the theoretical reaction is:

$$2(AuCy \cdot KCy) + Zn = ZnCy_2 \cdot 2KCy \cdot + 2Au,$$

by which 1 part of zinc should precipitate 6 parts of gold. But in actual practice 8 parts of zinc are consumed per 1 part of gold in the best cases, while in the worst as much as 40 parts of zinc are used. This not only wastes zinc, but it wastes cyanide also, and it has been repeatedly observed that unless the solution contains a certain percentage of potassium cyanide before passing over the zinc, the precipitation of the gold is incomplete. The caustic potash formed in the solution of the gold (see Elsner's reaction), acts on the zinc to dissolve it, forming potassium zincate and setting free hydrogen, while the zincate reacts on the cyanide to form double cyanide of potassium and zinc. If

the solution is very dilute, zinc will not precipitate the gold satisfactorily. Molbenhaur tried to use aluminum, but it costs more than zinc, and soon becomes coated with alumina, thus stopping its reaction on the solution. Molloy used sodium amalgam, the object being to re-form sodium cyanide and amalgamate the gold. The difficulty of producing and using the amalgam and the expense of distilling it were the chief defects of this method. In fact, for strong cyanide solutions, nothing has been found more efficient than zinc, while for dilute solutions a method of electrical precipitation is fast working its way to the front, and I will close my lecture with a description of Siemen's and Halske's electrical process.

In 1887, Dr. Werner von Siemens put up a small cyanide plant in Germany to work the Siebenbürgen gold ores, using electrolysis to precipitate the gold from the solution. In 1888, he was still working at the process experimentally in Berlin. In 1894, it was first put in actual operation on a large scale at the Worcester plant in the Transvaal, and is now being used at the following Transvaal mines:

	Tons.
Worcester Works, monthly capacity	3,000
Metropolitan Mine, " "	5,000
May Consolidated Mine, monthly capacity	6,000
Crœsus " " "	6,000
Robinson " " "	8,000
Present " "	32,000

Charles Butters, the prominent Transvaal engineer, prophesies that 100,000 tons per month will be treated by the electrical method of precipitation in 1897.

The original apparatus used consisted of a large rectangular box containing cathodes of sheet lead and anodes of iron arranged alternately. The anode surface in a single box was about 7,000 square feet, and each box precipitated about 50 tons of solution per day. The iron is slowly attacked, and forms ferro-cyanide of potassium and thence Prussian blue, while the lead is coated with gold until it carries 10 to 20 per cent. of its weight of gold, and is then

removed, melted down and cupelled. The electric current used is, of necessity, very feeble, being only 0·06 ampère per square foot of depositing surface.

The present practice is to economize space by making the lead cathodes in the form of lead shavings enclosed in bags. At one of the present plants there are four precipitation boxes, each 30 feet long by 4 feet 9 inches wide by 3 feet deep. Each has 1,100 square feet of iron anode surface, and 110 cathodes of bags, containing each 5 to 10 pounds of lead shavings. The tanks are in series; a current of 200 ampères by 10 volts runs the four boxes. Each box will precipitate 50 tons of solution per day, containing 80 grains of gold per ton to 15 grains, a total deposit of $(80 - 15) \times 50 = 3,250$ grains $= 0·464$ pound (average) gold per day (0·21 kilos). That this is an insignificant amount for the current passing (200 ampères), which should theoretically deposit 34·560 kilos in each box, is patent to the electrometallurgist, the yield being only 0·6 per cent.; but it must be remembered that the extraordinarily dilute solution used will not yield up its gold any faster, and that it must be electrolysed slowly to get any sort of correspondence between the power used and the gold obtained. There is still, however, plenty of room for improvement in both the zinc precipitation from the stronger solutions and the electrical precipitation from the weaker ones.

In conclusion, I would say that the cyanide process, while admirably adapted to some kinds of ores, is not at all to others; that it needs the best and most intelligent management, particularly on the chemical side, to render it successful; that there is still much room for improvement in its details; but that, given the right kind of ore and management, it is in most cases strikingly successful from both the metallurgical and economical points of view.

THE FUTURE OF AMERICAN INDUSTRIES.*

BY A. E. OUTERBRIDGE, JR.

GENTLEMEN:—The letter which I recently received from Dr. Lindsay, requesting that I would speak to you on this occasion upon a subject which has occupied my thought, and with the practical side of which I have had daily contact—or at least cognizance—for several years past, states that you are "interested particularly in the kind and quality of labor employed in this country, and in the social significance of improved labor-saving machinery."

Two years ago I had the pleasure of addressing your predecessors in this class upon the subject of the "Educational Influence of Machinery,"† and one year ago on "Pending Problems for Wage Earners."‡

I purpose on this occasion to attempt to cast the horoscope of manufacturing industries in America for the opening of the new century. In so doing, I will venture to express some views which may not be considered entirely orthodox from the viewpoint of the old-time manufacturer, who adheres tenaciously to the economic teachings of the fathers of American industries, and fails to see or recognize changed conditions which are plainly apparent to others. No one disputes the self-evident fact that the food which is adapted to babes is not sufficiently sustaining for strong men; so also, when our manufacturing industries were young and weak, they needed, for their growth and development, fostering care and protection from the attacks of older and stronger rivals; but now, when they have outgrown their swaddling-clothes, and have, in some instances, become giants in stature, of herculean strength, they are

* An address to students in Economics and Sociology in the Wharton School of Finance, University of Pennsylvania (December 18, 1896), with some additions and omissions for this publication.

† *Engineering Magazine*, May, 1895.

‡ *Popular Science Monthly* and *Jour. Frank. Inst.*, May, 1896.

prepared to go forth and conquer in the impending peaceful battles for the commerce of the world. To do this they must break away from the leading-strings of the good mother government, and fight with the superior weapons they have forged for themselves while under her care and tutelage.

It is my conviction that many of our industries have now reached this period of adolescence, or even of full vigor, and are well armed and prepared to explore new lands and to conquer new territories.

Advance couriers have already been sent "to spy out the land," and, if I may venture to claim any degree of prescience of the future, resulting from careful study of past industrial conditions, I would say that, with the coming of the twentieth century, new and greatly enlarged fields of operation will be opened up by energetic pioneers in trade, who will not hesitate to hew out new pathways for themselves, even though many laggards may eventually follow after at their leisure and avail themselves of the advantages which have thus been gained by the pluck and toil of the pioneers.

Disclaiming any political significance or intent in the color of these introductory words, I desire to confine my remarks to a study of present industrial conditions and their indications, which are in some respects entirely unique, and, therefore, not yet fully comprehended by the majority of observers.

The ability to perceive, in advance of others, the gradual budding or unfolding of future events—that quality of mind or temperament which we commonly call foresight—is a rare one, and prophecies are always somewhat *risque.* I therefore ask you to recognize a difference between the value of the statistics and statements of fact here given, and of the predictions regarding the future based upon these facts. The former may be accepted without hesitation, the latter with due caution, remembering that there are not a few manufacturers who would to-day surround this country with a sort of Chinese wall for the purpose of excluding the possibility of entrance of rival manufactured products, and,

of course, thereby incidentally preventing export of our own manufactures to new markets.

This subject affords an interesting and never-ending game of battledore and shuttlecock for political wranglers, in which we are not particularly interested; we will, therefore, pass over this phase of the discussion altogether.

The existing condition and future prospects of manufacturing industries in this country present interesting problems for study to the student, the statesman, the manufacturer and the wage earner.

It is evident, even to a casual observer, that many industries which have proved profitable in the past have been over-stimulated; improved facilities for manufacturing have outstripped the capacity for home consumption.

Competition has lowered prices, wages have fallen, production has been curtailed (more especially during the past three years) and hardships have resulted therefrom.

Further curtailment of production, or else enlargement of markets, must prove the solution in the near future of this important economic problem, and the key to the situation may, perhaps, be found in the recent reports of the Bureau of Statistics in Washington.

These statistics show that exports of American manufactures are increasing year by year, thus proving that we are now successfully competing in the markets of the world with the manufactured products of cheaper labor in foreign countries.

Although complete returns for the year 1896 are not yet available, it is safe to estimate, from the figures furnished in the past eleven months, that the total exports of manufactures for the year will equal, if they do not exceed, $250,000,000. This will be about $50,000,000 more than in 1895, which figures were, in turn, about $25,000,000 more than those of 1894.

Subtracting from the total those items which do not involve elaborate mechanical processes (such as petroleum, copper ingots, etc.), it appears that about 70 per cent. of the value includes a great variety of manufactures in which skilled labor forms the largest element of cost.

These divisions include: Agricultural implements; sewing-machines; typesetters and typewriters; watches and clocks; boots and shoes; locomotives and other machinery; machine tools and hardware; electrical supplies and scientific apparatus.

It has heretofore been maintained—and, indeed, is still contended—by many manufacturers, that the relatively high wages paid to skilled labor in America, as compared with wages in European countries, preclude the possibility of successful competition; but facts are more convincing than theories.

Within the past few years several large manufacturers, thinking to avail themselves of cheaper labor abroad, have established branches of their works in different parts of Europe; the same equipment of labor-saving tools and, as far as possible, the same systems of management were employed.

The result in each case proved a surprise. American labor, though highly paid, is so much more efficient that it has been thus shown to be cheaper in the end than that of poorly paid operatives in Europe. Several specific instances of this kind might be given if space permitted. Exact imitations of American manufactured products, including machine tools, have been made in France, but they have cost more to produce there than the importation of the genuine articles cost.*

It has been contended that freight rates on all heavy manufactured articles would surely always prove a prohibitive handicap. Facts again disprove theories. Two years ago an Alabama furnace sent an experimental shipment of 250 tons of pig-iron to England. This was considered an "exceptional case," and was also pronounced a visionary project and derided as ridiculous in the extreme.

Within this brief period, says the *Manufacturer's Record*, the demonstration is complete.

"From that experimental 250-ton shipment this business has increased until now there is an actual scarcity of steamer

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* *See Engineering Magazine*, January, 1897.

room to handle the business offered. Orders are being booked every week for large shipments to England and to Continental countries. It is difficult to rightly measure the influence of this trade upon the world's commercial interests."

From a recent statement by an officer of a leading furnace company, the foreign orders booked by that company alone amounted to about 40,000 tons, and inquiries under consideration between 30,000 and 40,000 tons. One of these, the same day on which this information was given, covering 5,000 tons, materialized into an order.

Pig-iron has already been shipped to Liverpool, Manchester, Rotterdam, Vienna, Genoa, Trieste, Yokohama and elsewhere abroad. These are facts not yet generally known.

Mr. John Fritz, in reviewing the history of the manufacture of pig iron during the past fifty years, at a recent meeting of the American Society of Mechanical Engineers, said that prior to 1840, when anthracite fuel was introduced in blast furnaces, the metal was nearly all made with charcoal, a good-sized furnace of that day producing 15 to 30 tons of pig iron per week. In a lecture on pig iron, which I delivered before the Franklin Institute in 1888,* I called attention to the fact that blast furnaces were then producing 1,000 tons of pig iron per week, and still larger output might be expected in the future.

The Carnegie Company is now building an extensive new plant at Duquesne, Pa., and furnace No. 1 is already in operation. During the past month (November) this furnace produced a daily average of 572 tons of standard Bessemer pig-iron, something hitherto unprecedented, and at the same time lowered the record with respect to proportion of fuel and cost per ton; 1,600 pounds of coke sufficed to smelt a ton of iron.

This company now controls ore beds of enormous extent on the famous Mesabi Range, in Minnesota, from which it obtains its low phosphorous iron ore at phenomenally low

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* *Journal of the Franklin Institute*, March, 1888.

prices. It has taken from one mine alone—the Oliver—during the past year more than 800,000 tons, at a cost of less than 20 cents per ton, all charges included. The mining (so-called) consists in scooping out the hillside with steam-shovels and depositing the ore directly on the cars.

An idea of the capacity of this labor-saving machinery may be gained from the recent statement of Professor Winchell, that, in spite of certain unavoidable delays, "an output of 808,292 tons was made during the year with three shovels, one of which was idle about half the time."

The estimate of 20 cents per ton, here given, as cost of mining appears to be excessive, as Professor Winchell, who has itemized the factors going to make up the cost, states that the stripping charge per ton of ore, uncovered, does not usually exceed 6 or 7 cents per ton, and the cost of shovelling the ore out of its natural bed, after stripping, does not exceed 10 cents, and with a very large output may be less than half this amount.

Crude pig-iron stands near the bottom of the list of articles involving a high degree of skilled labor. American watches, on the other hand, head the list. Yet they are exported, in constantly increasing quantities, to all parts of the world.

Very recently, the American Consul at Bradford, England, reported as follows:

"One Bradford firm of jewellers alone has a stock of 20,000 Waltham watches. In addition, it has watches of the Elgin and other makes, and sells large numbers. American files, made by machinery, according to the testimony of Consul Meeker, compete with English hand-made files. He mentions one order, recently sent to this country, for 1,000 dozen, whereas an order for 200 dozen English files would be considered, ordinarily, as a large one.

"Go into any cutlery or hardware shop in Bradford," said Mr. Meeker, "and ask for shears, and you will be handed a pair bearing a Newark or Trenton, N. J., imprint. They are considered superior in every way, and one of the strange things about it is that they must be purchased through

Sheffield, which is supposed to be the rival of American cutlery manufacturers. These shears, a dealer said to me, are superior to all others, because they are 'sweet cutters.' The shears used by tailors and cutters are almost entirely of American make.

"Turbine water-wheels and printing-presses of American manufacture are also sold in Bradford."

The export of machine-made boots and shoes is rapidly growing, and has indeed already assumed large proportions.

Within a few years past, great improvements have been made in the shoemaking machinery and in the product, accompanied by an equally noticeable reduction in cost.

Few persons are aware of the present extent of this business, which has grown up from very small beginnings. Statistics show that, in the census year of 1890, no less than 179,500,000 pairs of boots and shoes were made in factories in this country, by 194,000 operatives, an average of nearly 1,000 pairs per annum for each employee, and an average of nearly 3 pairs of shoes for every inhabitant.

A single factory, employing 233 hands (chiefly girls), turned out 2,100 pairs of women's shoes a day.

The best qualities of machine-made shoes are now fully equal to the best hand-made shoes, and are produced at one-third the cost; this accounts for their favorable reception in a number of new markets, in spite of former prejudices and of occasional misrepresentations of rivals, who naturally fear loss of business.

Seven thousand tons of steel rails, besides enormous quantities of other railroad material, are now being made in Pittsburgh for Japan, and large orders have, it is said, been booked for China.

A complete locomotive-manufacturing plant was recently shipped from Philadelphia to Russia, and railroad machinery is now on its way from this port to Australia.

A multitude of similar illustrations could be given, but these will serve as straws to show the direction in which the "trade-winds" are now blowing, and it only remains for American enterprise to take advantage of the opportunities which favorable circumstances offer to enter upon a new era of industrial prosperity.

The secret of success in these tentative experiments is to be found in the wonderful advances which have been made in labor-saving machinery, supervised by intelligent, highly paid operatives, whereby the productive capacity of each employee is enormously increased and the cost per unit of product correspondingly reduced.

The possibilities of reduction in cost of manufacture of any given articles are not always appreciated first by those who are most familiar with the routine methods. New departures are apt to emanate from those who approach the problem from a new standpoint, unbiased by old traditions.

A striking illustration of rapid changes in methods, and concomitant great reduction in cost of manufacture, is furnished in the recent history of the evolution of the incandescent electric lamp.

In 1880, I visited Edison's laboratory at Menlo Park, to inspect his new system of incandescent electric lighting.* I was then much impressed with the novel methods of making, in considerable numbers, the delicate lamps and filaments, and regarded them as marvels of mechanical ingenuity.

I understood, at that time, that Mr. Edison had succeeded by his methods in reducing the cost of manufacture of the little lamps one-half—*i. e.*, from about $3 to $1.50 each.

To-day, lamps, far superior to the earlier forms made in 1880, are sold in large lots at less than 20 cents each! A single factory of the General Electric Company turns out 6,000,000 a year, and the output of all the factories combined is about 20,000,000 lamps per year.

It is interesting, in view of the present low cost of the lamps, to know that the carbon filament is estimated to be, weight for weight, the most valuable substance known.

Filaments for the ordinary 16-candle-power lamps are worth $10 a thousand, and 14,000 are required to weigh 1 pound.

The filaments in the tiny bulb lamps used for surgical and dental purposes are very much smaller, and are three

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* For description, see *Journal of the Franklin Institute*, March, 1880.

times more valuable if estimated by weight, or more than $400,000 per pound.

Formerly, it was customary to estimate approximately the cost of a locomotive at $1,000 per ton weight. Thus, an engine weighing 40,000 pounds would cost about $20,000. To-day, a first-class locomotive, weighing about 130,000 pounds, costs about $8,000, or less than 6¼ cents per pound. Labor-saving machinery and "piece-work" systems of pay are largely accountable for these results.

The Pennsylvania Railroad has made an interesting, almost startling, discovery of the value of the piece-work system of remuneration in its shops at Altoona, as compared with the "days'-work" plan formerly in vogue.

An elaborate description of these methods, and of the results attained, may be found in the current number (December) of *The American Engineer, Car Builder and Railroad Journal*.

It is stated that, before the introduction of the new system, fifty new locomotives per annum represented the capacity of the shops. Since that change, the output—with substantially the same tools and appliances—has doubled. "The cost of days' work in the erecting shops of what are known as Class I engines was $290. The same amount of work, on engines of the same general class, but about 15 tons heavier, now costs $95.75, and is done in one-half the time. * * * By days' work it took three days to build a box car. This work is now done in fifteen hours.

"The pipe work on a locomotive formerly cost $137, and now costs $32."

Figures are given, showing that, while the output has been doubled and cost of labor reduced one-half, wages have been raised more than 25 per cent. under the new system.

The value of this change may be better appreciated when it is stated that the cost of equipment on the Pennsylvania Railroad last year was $9,500,000, of which about $4,750,000 was labor.

In conclusion, I may repeat what I have said on a former occasion that the introduction of labor-saving

machinery has enormously increased the output for each workman, and this introduces a new element into the ethics of the question of wages, and also into the practical question of cost. If it can be shown that a skilled workman, at a slight increase of labor and attention, can enormously increase the output of a machine, he should be encouraged to make the effort by an increase of pay.

An increase of output must logically and necessarily involve a fair increase of wages, and, in a properly conducted business, this increase of wages, following increased output, must mean increased profit.

This is a profit-sharing scheme to which there can be no practical objection.

While the brief statements here given are intended merely as indications of the present and prospective condition of manufacturing industries in America, they seem to point clearly to the encouraging fact that this country is about to enter upon an era of industrial prosperity through growing expansion of its commerce and manufactures.

COMPRESSED AIR FOR CITY AND SUBURBAN TRACTION.*

BY HERMAN HAUPT.

[*Concluded from p. 26.*]

RESULTS OF TESTS.

Compressed air motors have long since passed the experimental stage. They have been running for two years at Rome, N. Y., and through the kindness of the officials of the New York Central Railroad have been repeatedly allowed to run on the main track, where a speed has been attained of 30 miles per hour with wheels of only 26 inches diameter.

It should be obvious to every person of intelligence that

* Read by title, November 18, 1896.

a compressed air motor can be planned to fulfil any conditions, or perform any service, within the capacity of a steam locomotive. Speed requires large wheels, length of run large storage. High grades and heavy trains require large cylinders. The motor must be adapted to its work and fulfil the conditions of its service.

Tests have been made repeatedly by engineers and experts from all parts of the country, all of whom, without exception, have made favorable reports. One of these tests, made in the presence of the writer and of Captain Fiebeger, of the U. S. Engineers, February 18, 1895, gave the following results:

Starting with a pressure of 1,900 pounds in motor, and temperature of 291° in the water of the reheating tank, the first six runs of 4,800 feet were made on an average of 221½ cubic feet of free air per mile.

The next six runs of 4,800 feet, temperature 252°, required an average of 339 cubic feet per mile.

The water in the tank was then reheated, by attaching a steam hose, to 302°, when the next run was made on an average of 208½ cubic feet per mile, from which the required quantity of air increased as the water became colder to 377 cubic feet per mile. After the tenth run, the water was again reheated, and the quantity of air fell per mile to 247 cubic feet, and then increased to the fifteenth and last run, when the temperature was 247° and the quantity of air per mile 521 cubic feet.

The average expenditure of air during the whole test was 308 cubic feet per mile. When the water was emptied from the tank and cold air used, the consumption was 661 cubic feet per mile on the same track.

This motor was calculated to run a maximum distance of 12 miles, with one charge of air, but as the reservoir capacity was 35 cubic feet, under 136 atmospheres, the cubic contents of free air was 5,760 cubic feet, which, divided by 308, gives 18·7 miles as the possible run if all the air could have been used. Allowing 2·7 miles as a reserve, there would still have remained an effective run of 16 miles. There can be but little doubt that by an efficient system

of reheating, whereby the temperature could be maintained at 300°, a greater efficiency could be secured.

It is unnecessary to give the results of other tests; they have been quite numerous, and by different experts, and confirm substantially the conclusion above stated.

The motors now running daily on the One-hundred-and-twenty-fifth Street railway in New York make 17 miles with one charge of air. The reservoir capacity, 50 cubic feet.

Why is compressed air cheaper, both in installation and in operation, than any other system of traction for city and suburban service?

It requires less power at the power station for a given service, and this means less cost for engine plant and a perpetual saving in coal consumption.

A comparison with the trolley must be based on similar conditions, and as the recognized maximum distance of transmission of electrical power under 500 volts is 5 miles, a line of 5 miles, double track, with two-minute headway, will be assumed as a basis of comparison, average speed 10 miles per hour, and 30 motors on line.

Electrical motors are usually supplied with two 25 horse-power motors, making 50 horse-power each, but as the full power is required only in overcoming the maximum resistances, the power provided at the power station is usually calculated upon a basis of transmission of 25 horse-power for each motor.

This transmission involves many losses, and only a comparatively small portion can be actually utilized at the rail.

In the *Engineering News* of October 17, 1895, p. 256, is found the following estimate, the indicated power of the engine at the power-house being taken at 100:

	Per Cent.		*Per Cent.*
Engine friction	8	Remains	92·0
Belting and shaft	10	"	82·5
Dynamos	8	"	76·2
Transformers at power station	7	"	70·9
Line to sub-station	12	"	62·4
Transformers at sub-station	7	"	51·8
Rotary converter	16	"	48·8
Railway circuit	10	"	43·8
Car motor	15	"	37·2

This estimate gives only 37·2 per cent. of the indicated power at the station as effective at the rail; but as other estimates claim a higher efficiency, it will be assumed as 50 per cent.

The thirty motors on the track will therefore require 1,500 horse-power as the prime mover at power-house.

Thirty air motors, with a run of 10 miles, will require 4,000 cubic feet of free air, or 2,000 cubic feet per minute, compressed to 2,000 pounds, and the horse-power at the station will be 900, or 600 less than with electricity, and there is no loss in transmission.

COMPARATIVE COST OF MOTORS.

It is usually claimed that the cost of compressed air motors is considerably greater than the cost of electrical motors for equal service.

This is a mistake; the comparison must be made under like conditions. The compressed air motor carries its power with it. The electric motor takes it from the line. A fair and just comparison requires that the cost of plant to furnish power on the line should be included or omitted in both cases.

Omitting the reservoirs, estimates for the air motors have been brought below the electric motors, notwithstanding the low price of the latter, due to active competition; but allowing the cost to be the same in both systems, a comparison will be made between the reservoirs for thirty motors and the line construction required to furnish the electrical power for an equal number.

The thirty air motors will require 110,000 pounds of reservoir, costing about $15,000; per motor, $500.

The cost of line work for 5 miles of double track, with thirty motors, will be $26,000; per motor, $866.

POWER PLANT.

Another great saving is effected in the cost of power plant. It is usual in electrical estimates to allow $80 per horse-power at the power station, exclusive of land and

buildings for engines, boilers, shafting, belts, dynamos and other apparatus.

The cost of 1,500 horse-power, at $80 per horse-power, would be $120,000.

Compressed air requires no dynamos, belting or shafting. Steam from simple boilers is piped directly to the compressor, and it would be an excessive estimate to assume that the cost is one-half that of electricity, or $60,000.

SAVING IN TRACK.

The track for air motors requires no girder rails or electric binding or welding. A simple cross-tie track, as is used for ordinary locomotives, is sufficient. The reason for this is that the weight on the air motor is spring-supported, and on the electric motor a much heavier load is rigidly attached to the axle. From a table furnished to the writer by Franklin L. Pope, it appears that the effect of a blow of 1 ton from a wheel passing over an obstruction $\frac{1}{8}$ inch in height, at a speed of 20 miles per hour, is twenty-seven times as great when the weight is rigidly attached as when it is relieved by springs.

The saving with compressed air increases with the magnitude of the plant. Without encumbering this paper with detailed estimates, it is proper to state that the writer prepared a close estimate of the relative cost of electricity and compressed air for a transmission of 5 miles from the power station on an elevated railroad, such as the Third Avenue Railroad, in New York, with trains running at one-minute intervals. The estimate for electricity was submitted to a prominent electrical engineer and pronounced correct. The cost was more than double that of the compressed air installation. In fact, the return electrical current could not be transmitted in the ordinary way by rail, but would require some special arrangement. The attempt to reduce the cost of copper by increasing the voltage of transmission is attended with great increase of risk to life.

A system that may prove satisfactory on a small scale and with a limited volume of business may result in failure

if extended beyond certain limits. President Vreeland, of the Metropolitan system, in New York, in an interview recently published in the *Herald*, pronounced the underground electric system in Lenox Avenue unsuited for a line with a heavy business. It required sometimes from two to four days to locate a defect, which, when found, could be remedied in ten minutes.

In selecting any system for adoption, the sensible course is always to get estimates in detail from competent and unbiassed engineers, covering every point of installation and of operation, and then find responsible contractors to guarantee the work within the limits of the estimates.

COST OF OPERATION.

It has been shown that the cost of installation of a compressed air system is much less than that of the ordinary cheap trolley with wooden poles. If it can be shown also that the operation is more economical, then there can be no question as to its superiority in this particular over the cable, underground electric and other systems, all of which are much more expensive than the trolley.

The following is the latest revised estimate of an engineer long connected with electric companies and familiar with all details of operation, but at present engaged in the introduction of compressed air installations:

MOTIVE POWER PER CAR MILE (run 120 miles per day).

	Cents.
Anthracite coal for compressor plant	0·870
Anthracite coal for reheating	0·110
Water, boiler-feed, etc.	0·022
Oil, waste, etc.	0·024
Removal of ashes, etc.	0·014
Operating labor	0·615
Maintenance of power plant, etc.	0·163
Maintenance of motors, etc.	0·280
Interest and general expenses	1·760
	3·858

TRANSPORTATION.

	Cents.
Maintenance of cars, trucks, buildings	1·619
Motormen, conductors, etc.	6·133
General expenses, interest, etc.	1·155
	12·765

Electricity, similar items included, costs	16·268
Difference, 27 per cent.	3·503

SOME INTERESTING FACTS.

By reheating the air required for the operation of a motor, the efficiency may be so much increased that more power may be utilized in the motor cylinders than was expended at the power station in the compression of the air.

This statement has often elicited a smile of incredulity as it seems to be in violation of the law of the conservation of energy, but it is susceptible of a simple explanation.

Take the horse-power at the compressor, say 1,400 horse-power to compress 3,600 cubic feet of free air per minute to 2,000 pounds, the foot-pounds in 10 hours would amount to 5,544,000,000.

The number of motors that this amount of air would supply is 120, assuming cylinders 6 x 14 inches; wheels, 26 inches in diameter; speed, 6 miles per hour; consumption of free air, 300 cubic feet per mile; pressure, 140 pounds per square inch, cut off at one-tenth stroke; mean pressure, 46·2 pounds per square inch. These conditions would give 6,802,272,000 foot-pounds of work in the cylinder of the motors, or 22 per cent. more than the foot-pounds of power expended at the compressor.

How can this be explained? Simply by the reheating of the air, which increases its volume and by the steam which accompanies it and adds greatly to the effect.

But if air is reheated and steam used as an auxiliary to increase the effect, will not the expense of reheating fully offset any advantages thereby secured?

COST OF REHEATING.

From tests made in 1879, it was found that for 50 cubic feet of free air passed through the reheater, 1 pound of water, in the form of steam, was absorbed; 300 cubic feet of air would, therefore, absorb 6 pounds of water. Under a pressure of 140 pounds, the temperature would be 353°, or for effective pressure of 140 pounds, the absolute pressure

would be 160 pounds and temperature 364°. The latent heat at this temperature is 858°.

The heat units required to raise 6 pounds water from 60° to 364°, including the latent heat, will be $1,162 \times 6 = 6,972$ units. To raise the temperature of 300 cubic feet of air 23 pounds, from 60° to 364°, specific heat of air being 0·24, will be $304 \times 23 \times 0·24 = 1·678$ units.

The total units required for reheating for 1 mile will, therefore, be $6,972 + 1,678 = 8,650$ units, which would be supplied by four-fifths of 1 pound of coal, at a cost of $1\frac{1}{5}$ mills.

This coincides very nearly with Mr. Hardie's experience, that the cost of reheating was about one-eighth the cost of compression.

EXPANSION IN REHEATING.

Fifty cubic feet of dry air carries over 1 pound water, which in steam, at atmospheric tension, gives 52 per cent.

Air at 60° F., heated to 364°, will expand in proportion of $461 + 60$ to $461 + 364$, or 521 to 825, which is 58 per cent. Total increase of volume, 110 per cent. Hence, 300 cubic feet will become 633 cubic feet. Without reheating the water on the trip, the Hardie motor, at Rome, consumed 331 cubic feet per mile, 110 per cent. of which would be 695 cubic feet. The actual consumption of dry air was 661 cubic feet.

INFLUENCE OF SPEED IN CONSUMPTION OF AIR.

A very general, but very erroneous, impression appears to exist in regard to the increased consumption of air in traction motors, due to an increase of speed.

It is assumed that the consumption of air must be in proportion to the horse-power, and as the space passed over in a given time must be doubled, the horse-power, in which space is a factor, must be doubled, and the consumption of air doubled also.

This is true, but the consumption of air *per mile* is not doubled by doubling the speed. The consumption of air is in proportion to the resistances to be overcome, and within

reasonable and ordinary limits these resistances are but slightly increased by increase of speed. It is an error, also, to suppose, as many do, that in trolley motors an electrical attraction between the wheel and rail increases adhesion.

In support of these positions, authorities will be quoted. Oscar T. Crosby, in *Transactions* of American Institute of Electrical Engineers for August and September, 1894, states: "The adhesive coefficiency between the wheel and the rail is not increased in any practical degree by the passage of the current. In other words, there is no electrical attraction, as some suppose, between the wheel and the rail to increase adhesion. The adhesion is due to the weight on drivers alone."

The train resistances at high speeds do not increase, as is usually supposed, as the square of the velocity. At 86 miles per hour the total resistance per ton was only 13·4 pounds; 347 tons were carried at 86 miles per hour on a line by an expenditure of 1,068 horse-power.

The resistance of the air is a function of the first instead of the second power of the velocity.

From 40 to 80 miles per hour, the tonnage coefficient is practically 8 pounds per ton on first-class roads and best rolling stock.

Wellington, in his popular work on engineering, pages 922–924, makes statements as follows:

"Journal friction is variable, and is usually taken at 8 pounds per ton.

"The load per square inch on journal bearing has very little influence upon the friction.

"The velocity of the lowest journal friction is from 10 to 15 miles per hour.

"With good lubrication there is very little increase of journal friction up to 55 miles per hour.

"The coefficiency of journal friction is approximately constant at velocities from 15 to 50 miles per hour.

"The power required to overcome inertia and accelerate trains is about three times as much as to maintain velocity.

"The additional power required to get up speed is 45 pounds per ton to give 15 miles per hour in 3,340 feet.

"The air resistance at 10 miles per hour is less than $\frac{1}{5}$ pound per square foot.

"The principal resistance, except axle resistance, is due to oscillation and concussion, which, at 10 miles per hour, may be taken at $\frac{1}{2}$ pound per ton."

The above quotations from standard authorities do not sustain the statement of the expert of the General Electric Company, who stated in a criticism upon an estimate of the writer, that "a calculation, which it is not necessary to enter into, will show that to make an approximation to the average speed of 20 miles per hour, 600 horse-power will be found *not* sufficient to do the work. Where the speed of an electric train is reduced to that assumed for the steam train (10 miles per hour) 300 horse-power will be found abundantly sufficient."

The inference would appear to be, that if the speed of an electric train is increased from 10 to 20 miles per hour, the power must be increased from 300 to 600 horse-power. If this be true, it is very bad for electricity, for it is not true in regard to either steam or compressed air. The power required must always be sufficient to overcome resistance, and if, as appears from the authorities quoted, the resistances are but slightly increased by increase of velocity, there cannot be any great increase of power required per mile of distance traversed as measured by consumption of air or steam. There must be some, of course, but in ordinary service it does not figure very largely in the expenses.

As practical tests are more satisfactory than theory, the writer requested Mr. Hardie to make a test of the consumption of air at different speeds, and report the result. The following is the report, under date of April 22, 1896:

FIRST TEST. LOAD, 19,150 POUNDS.

Speed.		*Cubic Feet per Mile.*
3·00	miles per hour, consumption of air	347
5·70	" " " " "	334
6·81	" " " " "	488
7·57	" " " " "	335
7·80	" " " " "	568
8·50	" " " " "	452
9·70	" " " " "	388

Speed.		*Cubic Feet per Mile.*
10·10	miles per hour, consumption of air	560
10·30	" " " " "	275
11·40	" " " " "	604
12·30	" " " " "	421
13·00	" " " " "	538
13·70	" " " " "	447
16·70	" " " " "	450
17·05	" " " " "	447
22·80	" " " " "	445

SECOND TEST. LOAD, 24,990 POUNDS.

12·27	miles per hour, consumption of air	334
15·34	" " " " "	449

THIRD TEST. LOAD, 26,100 POUNDS.

6·70	miles per hour, consumption of air	437
8·00	" " " " "	452
10·34	" " " " "	470

FOURTH TEST. LOAD, 36,000 POUNDS.

5·25	miles per hour, consumption of air	632
7·50	" " " " "	582
8·56	" " " " "	589
15·34	" " " " "	334

The above results are very remarkable. The ordinary pressure gauges are not very sensitive, but it is impossible, from the above table, to infer that there was any increased consumption of air per mile, either with a largely increased speed or a considerable increase of weight. When a train is in motion, the draw-bar pull is but slightly increased by a moderate increase of speed. The great losses of power are in acceleration and retardation in starting and stopping.

It has been stated that the power required on a good track to start a street car is 116 pounds per ton, and to maintain it in motion 13 to 17 pounds. On a bad track, 134 pounds to start and 35 pounds to maintain.

Mr. Hardie has found by tests upon his motor that 130 successive applications of the brake consumed, by gauge pressure, 85 cubic feet of free air, equivalent to 0·65 cubic feet for each application.

Franklin L. Pope is authority for the following statement:

"A 16-foot trolley car, weighing about 14,000 pounds, requires eighteen seconds to get up speed and 10 horse-power to run 10 miles per hour, or 1 horse-power per mile per hour at car axle. Three times this power is required during the eighteen seconds of starting."

Frank S. Sprague, in New York *Evening Post*, of February 8, 1896, states that on the Third Avenue Elevated Railroad the maximum effort in the propulsion of trains is seven times the mean traction on a level; and that to start a train, accelerate to 20 miles per hour and bring it again to rest, consumes eighty seconds.

David L. Barnes estimates that an elevated train of 130 tons can be accelerated to 30 miles per hour in a distance of 1,250 feet, and brought to rest in half that distance.

OTHER USES FOR COMPRESSED AIR.

Compressed air affords the most economical means for the transmission of power to long distances. It has been claimed that electrical power generated from waterfalls could be transmitted hundreds of miles, but the writer has attempted to show in a monograph that is too voluminous to quote, that in the present condition of the science, power by electricity cannot be economically transmitted in competition with power furnished locally by coal, to a greater distance than about 20 miles. Long electrical transmission requires excessively high voltages, which are almost impossible of permanent and successful insulation, and instantly destructive to life in case of accidental contact. The late lamented Franklin Leonard Pope, in a letter to the writer, used this language: "A voltage of 20,000 may be possible in the future, but it has not yet been successfully accomplished. The difficulties seem to increase roughly as the square of the voltage; 10,000 volts is a wicked acting current, and when you double it, you had better watch out." He also adds: "The same speculative boomers who have put in 300 non-paying electric railroads throughout the country are now at work fostering a craze on electric power transmission. I am

sorry to see it, for it will end in discrediting all legitimate electric work. The mass of people will never learn to discriminate between the practicable and impracticable."

The transmission of compressed air requires high pressures, for the reason that increased pressure gives increased density and reduced volume and velocity. The loss in transmission being as the first power of the density and the square of the velocity, the loss in transmitting under 200 pounds would be ten times as great as under 2,000 pounds. High pressures are necessary for economical transmission both with electricity and air.

But compressed air and electricity are not properly to be considered antagonists; they may be made valuable auxiliaries.

A 6-inch pipe under an initial pressure of 2,000 pounds per square inch, and a terminal pressure of 10 atmospheres, or 147 pounds, will transmit nearly 8,000 horse-power to a distance of 10 miles, 5,700 horse-power to 20 miles, and 2,500 horse-power to a distance of 100 miles. Where there are mountain streams furnishing small powers at frequent intervals, a number can be concentrated in one pipe, and transmitted to furnish large power in distant localities. Compressed air, thus economically transmitted, can be used to generate electricity for local purposes. It can also be distributed to provide small powers, and also for ventilation and refrigeration in towns and cities.

The cable and electric systems, it is well known, are operated to best advantage economically at full capacity, but this is only for a few hours in the day. If surplus power were used to store air at high pressure in reservoirs the machinery could be shut down entirely or partially, and compressed air motors substituted at night and during the hours when full capacity is not required.

ELASTICITY OF THE SYSTEM.

An important advantage of compressed air motors is found in the fact that each motor is independent, and unaffected by any derangement of feed or trolley wires, cables or dynamos. They can run on any line, in connection

with any other system, and at any rate of speed. The introduction of air motors can be gradual; one motor can be tried, and, if satisfactory, the number can be increased to a full equipment. The steam required for electric or cable lines can furnish the little that is required for an experimental compressor, and will be more than sufficient for a full equipment. No outside expenditure whatever is required—no conduits, poles or wires. In this respect it differs from other systems, and permits a test to be made at a minimum of cost; but compressed air motors can no longer be considered as experiments. While they may not have attained the utmost limit of perfection of which they are capable, the experience in Europe, in Rome, N. Y., and in the City of New York, should be sufficient to satisfy the most skeptical.

SPEED VARIATIONS IN CRANK SHAFTS.

BY GEORGE P. STARKWEATHER.

A portion of the following discussion has appeared in cruder form in two numbers of the *Yale Scientific Monthly*, a magazine conducted by and for the students of the Sheffield Scientific School. Subsequently the writer pursued the matter further, and thought the whole to be of sufficient interest to warrant a wider publication.

The so-called exact method of discussing engine dynamics, as given in Prof. D. S. Jacobus' paper (see *Trans. A. S. M. E.*, Vol. XI), is inexact in one particular, namely, that in calculating the acceleration of the reciprocating parts of the engine the angular speed of the crank is assumed to be constant. The error thus introduced, however, is inappreciable. As this method is very laborious, the following simpler one is given, which, excepting that it does not take friction into account, is quite as exact. It has the drawback that the only joint pressure obtainable is the tangential component of the crank-pin pressure. Afterwards, a method for correcting the above-mentioned error is shown.

In *Fig. 1*, *a-c-e-f* is the indicator diagram, the back and full pressure lines being taken, of course, from opposite cards, so as to obtain the effective piston pressure; $O\,P$ is the crank, $P\,B$ the connecting rod, G the center of gravity of the latter, and C its instantaneous center of motion. Let M be the mass of the rod, and I_1 its moment of inertia about G. In obtaining M, I_1 and the position of G, the mass of the piston, piston-rod and crosshead is considered as a part of the connecting-rod concentrated at B; this is evidently allowable so far as considerations of energy are concerned.

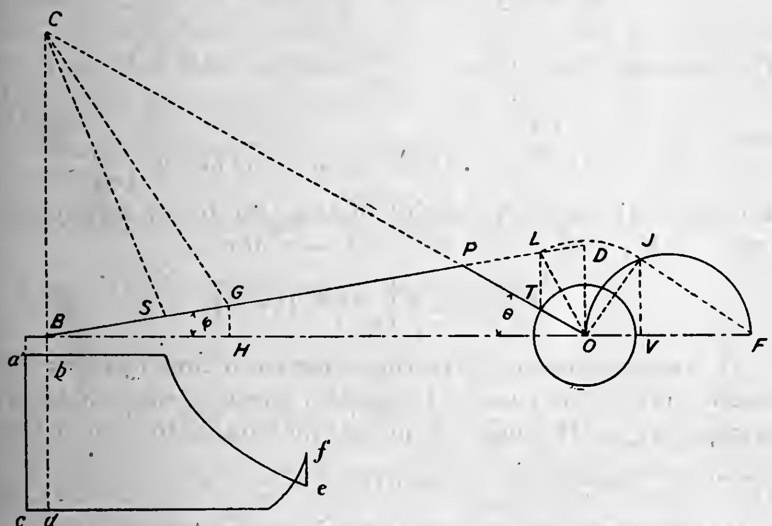

FIG. 1.

Let I' be the moment of inertia of the rod about C, and w' its angular speed about the same point, w_a being the average angular speed of the crank. Represent $O\,P$, $G\,P$, $B\,P$, $G\,H$, $C\,P$ and $C\,G$ by r, $l\,r$, $m\,r$, h, p and a, respectively. Then the energy of the rod is $E = \frac{1}{2}\,I'\,w'^2 + M\,g\,h$, the potential energy due to the weight being reckoned from the level $B\,O$. (For vertical engines, instead of h, we would use $O\,H$.)

Now, $$w' = \frac{r\,w_a}{p}$$

and $$I' = I_1 + M\,a^2;$$

so $$E = \frac{r^2 w_a^2}{2 p^2} (I_1 + M a^2) + M g h.$$

Also, $$a^2 = l^2 r^2 + p^2 - 2 p l r \cos(\theta + \varphi),$$

and $$h = \frac{(m - l)}{m} r \sin \theta;$$

so

$$E = \frac{w_a^2}{2} \left[\left(\frac{r}{p}\right)^2 (I_1 + M r^2 l^2) - \left(\frac{r}{p}\right) \left\{ 2 l M r^2 \cos(\theta + \varphi) \right\} + M r^2 \right] + M g \frac{(m - l)}{m} r \sin \theta,$$

where φ is given by $\sin \varphi = \frac{\sin \theta}{m}$,

and $$\frac{r}{p} = \frac{\cos \theta}{m \cos \varphi} = \frac{1}{\sqrt{m^2 + (m^2 - 1) \tan^2 \theta}}.$$

(For vertical engines, instead of the last term, we would have $M g \overline{OH} = M g (l r \cos \varphi + r \cos \theta)$

$$= M g r \cos \theta \left[\frac{l}{m} \left(\frac{p}{r}\right) + 1 \right].$$

This expression for E is the same for θ and $(360° - \theta)$, except that, in the case of horizontal engines, the last term changes sign. It must be noted that for values of θ between 90° and 180°, $\frac{r}{p}$ is negative.

If it be desired to neglect the side swing, and to assume that the connecting rod has the same motion as the piston, which is commonly done, we have only to set l, I_1 and h equal to m, o and o, respectively. We have then

$$E = \frac{M r^2 w_a^2}{2} \left[m^2 \left(\frac{r}{p}\right)^2 - 2 m \left(\frac{r}{p}\right) \cos(\theta + \varphi) + 1 \right].$$

But E can be obtained graphically with the greatest simplicity. We may consider the connecting-rod to consist of two material particles, provided these have the same total masses, the same center of gravity and the same inertia about that center. Let m_1 and m_2 be the masses of these particles, p_1 and p_2 their distances from G along the line of

the connecting-rod, and k the radius of inertia of the rod about G. Then

$$m_1 + m_2 = M, \quad m_1 p_1 = m_2 p_2, \quad m_1 p_1^2 + m_2 p_2^2 = M k^2,$$

which give $p_1 p_2 = k^2$.

Choose p_2 such that m_2 will lie at P, and let S be the corresponding position of m_1. Draw a circle of radius $O\,T$ such that $O\,T : O\,P = B\,S : B\,P$. Where this intersects $O\,P$ project vertically to L, on the connecting-rod line. Then as the triangles $O\,P\,L$ and $C\,P\,S$ are similar, if we take $O\,P$ to represent the velocity of the crank-pin, $O\,L$ will represent the velocity v_1 of m_1.

Lay off $O\,F$ to represent $\frac{2}{m_1}$, and on it as a diameter draw the semicircle $O\,J\,F$. With O as a center draw the arc $L\,J$, and drop the vertical $J\,V$. Then from the similar triangles $J\,V\,O$ and $F\,J\,O$

$$O\,V = \frac{O\,J^2}{O\,F} = \frac{O\,L^2}{O\,F}.$$

But $O\,L$ represents v_1 and $O\,F$ represents $\frac{2}{m_1}$;

so $O\,V$ represents $\frac{m_1 v_1^2}{2}$,

the kinetic energy of m_1, to some scale s_1.

As regards this scale, if s_2 equals the scale in feet per second per inch to which $O\,L$ represents v_1, and

$$s_3 = \frac{2}{m_1\,O\,F},$$

$O\,F$ being measured in inches, it is easily shown that

$$s_1 = \frac{s_2^2}{s_3}.$$

The kinetic energy of m_2 can be easily found, it having the velocity of the crank-pin, assumed as constant. Adding this to that of m_1, and measuring h, the total energy E is obtained.

Here again, if we consider the connecting-rod to have the same motion as the piston, m_1 becomes M (sometimes taken $\frac{2}{3}\,M$) and $O\,L$ becomes $O\,D$.

When the crank is at the dead point let the energy be E_0. Then, as p, a and h become $m\ r$, $(m - l)\ r$ and o, respectively,

$$E_0 = \frac{w_a^2}{2\ m^2}\left[I_1 + M r^2 (m - l)^2\right],$$

to which must be added for vertical engines $M\ g\ r\ (l + 1)$. Let W be the work done by the expanding fluid while the crank has turned through the angle θ; this is the area *a-b-c-d* in the figure, and can easily be determined by planimeter or ordinates. Since the energy of the connecting-rod has changed from E_0 to E, the work transmitted to the crank-pin is $W - (E - E_0)$. In *Fig. 2* lay off as an abscissa $N\ L$ to represent θ, and as an ordinate $L\ M$ equal to this total work transmitted to the crank-pin; plotting in this way we obtain a curve of total crank-pin work $N\ M'\ M\ Q$. The resistance being in general constant, the work done

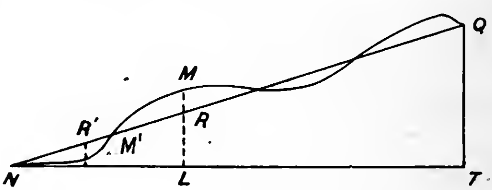

FIG. 2.

upon it is represented by a straight line, and since for a revolution it is the same as the work done on the crank-pin, the line is $N\ R\ Q$.

Consequently, $R\ M$ represents the energy gained by the fly-wheel while it has turned the angle θ, for it is the difference between the work received at the crank-pin and that transmitted by the belt. Measure the greatest positive and negative values of this, $R\ M$ and $R'\ M'$; their sum represents the fluctuation of fly-wheel energy K, and the fly-wheel inertia is obtained by substitution in the usual formula

$$I = \frac{K}{k\ w_a^2}$$

where k is the coefficient of unsteadiness allowed.

$R\ M$ probably cannot be measured accurately, owing to the scale of the drawing. It is accordingly better to measure

N L or θ corresponding to *R M*. This can be very exactly determined, as it is convenient to take the scale of abscissas large; also, *R M* being a maximum, a small error in θ will affect the result very slightly. With this value of θ find the value of *L M* by the formulæ given, and *L R* by the similar triangles *N L R* and *N T Q*. This gives *R M*, and in like manner *R′ M′*.

This curve of total crank-pin work is mentioned by Prof. Cotterill, in his *Applied Mechanics*. He does not take the inertia of the reciprocating parts into account, however, and in this case it is, as he states, a longer method than that by resolution of forces. But, in the writer's opinion, it is a shorter method when the inertia is to be considered.

The slope of the curve is proportional to the tangential component of the crank-pin pressure; where the slope changes sign indicates a reversal of that pressure. Where the curve crosses the line *N Q* gives us the crank positions at which the fly-wheel has the same speed as at the dead point, and, in general, any ordinate *R M* gives the energy of the fly-wheel as related to its energy at the dead point. In our present case, the maximum *R M* is much greater than the minimum *R′ M′*, so the angular speed of the fly-wheel at the dead point is probably less than the mean speed.

The preceding determines the fly-wheel inertia to control the speed fluctuation as desired. Let us now suppose this inertia to be given or determined; we have to find the speed variations. It will be observed that if we find the speed at any one point, we have indirectly from *Fig. 2* the speed at every point, since, knowing the inertia of the fly-wheel, we know the difference between the square of the velocity at any point and that at the given point. Transfer the ordinates *R M* to a horizontal base line, obtaining a curve as in *Fig. 3*. Draw *P S* horizontal at such a distance below *N R* that some ordinate *M Q* represents the kinetic energy of the fly-wheel at that moment. Then the ordinates from *P S* give directly $\frac{1}{2} I w^2$, indirectly w, the angular velocity at any point. We have to find one ordinate.

A writer in London *Engineering*,* who obtains this curve in a different manner, finds an ordinate by making either of two assumptions:

(1) That the energy at the average speed is the mean of the extreme energies.

(2) That the average speed is the mean of the extreme speeds.

The latter is the assumption commonly made.

In the first case, calling w_1 and w_2 the extreme speeds,

$$\tfrac{1}{2} I w_a^2 = \tfrac{1}{4} I (w_1^2 + w_2^2).$$

We have also $\tfrac{1}{2} I w_1^2 - \tfrac{1}{2} I w_2^2 = R M + R' M'$,

from which $\tfrac{1}{2} I w_1^2 = \tfrac{1}{2} (R M + R' M' + I w_a^2)$,

giving the distance of $P S$ below M.

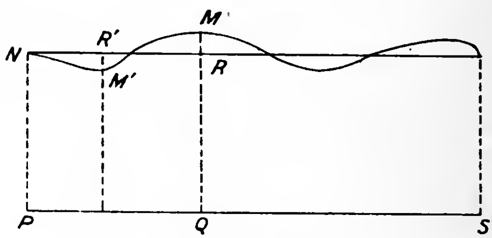

FIG. 3.

In the second case $w_a = \tfrac{1}{2} (w_1 + w_2)$,

also $\tfrac{1}{2} I w_1^2 - \tfrac{1}{2} I w_2^2 = R M + R' M'$,

from which

$$\tfrac{1}{2} I w_1^2 = \frac{(R M + R' M' + 2 I w_a^2)^2}{8 I w_a^2}.$$

But the ordinate $N P$ can be found exactly without any assumptions by determining w_0, the speed at the dead point, in the following manner: Call y any ordinate from $N R$ of the curve in *Fig. 3*, abscissas θ being measured from N. Then

$$\tfrac{1}{2} I (w^2 - w_0^2) = y \qquad w = w_0 \left(\frac{2 y}{I w_0^2} + 1\right)^{\frac{1}{2}}$$

or

$$\frac{d \theta}{d t} = w_0 \left(\frac{2 y}{I w_0^2} + 1\right)^{\frac{1}{2}}$$

* **22**, 1, 37.

from which $$d\,t = \frac{d\,\theta}{w_0}\left(\frac{2\,y}{I\,w_0^2} + 1\right)^{-\frac{1}{2}}.$$

Now, in every possible case, y will be less than $\frac{1}{2}\,I\,w_0^2$, for the alternate condition would mean that the resistance is so great that the engine comes to rest. So we can develop

$$\left(\frac{2\,y}{I\,w_0^2} + 1\right)^{-\frac{1}{2}}$$

by the binomial theorem in ascending powers of $\frac{2\,y}{I\,w_0^2}$, obtaining

$$dt = \frac{d\,\theta}{w_0}\left(1 - \frac{y}{I\,w_0^2} + \frac{3}{2}\,\frac{y^2}{I^2\,w_0^4} - \frac{5}{2}\,\frac{y^3}{I^3\,w_0^6} + \text{etc.}\right)$$

Integrating for θ between the limits o and $2\,\pi$, and for t between o and one period, $\frac{2\,\pi}{w_a}$,

$$\frac{2\,\pi}{w_a} = \frac{2\,\pi}{w_0} - \frac{1}{I\,w_0^3}\int_0^{2\pi} y\,d\,\theta +$$

$$\frac{3}{2\,I^2\,w_0^5}\int_0^{2\pi} y^2\,d\,\theta - \frac{5}{2\,I^3\,w_0^7}\int_0^{2\pi} y^3\,d\,\theta + \text{etc.}$$

Call these integrals respectively S_1, S_2, S_3, etc. Then

$$\frac{2\,\pi}{w_a} = \frac{2\,\pi}{w_0}\left(1 - \frac{S_1}{2\,\pi\,I\,w_0^2} + \frac{3\,S_2}{4\,\pi\,I^2\,w_0^4} - \frac{5\,S_3}{4\,\pi\,I^3\,w_0^6} + \text{etc.}\right)$$

or,

$$w_0 = w_a\left(1 - \frac{S_1}{2\,\pi\,I\,w_0^2} + \frac{3\,S_2}{4\,\pi\,I^2\,w_0^4} - \frac{5\,S_3}{4\,\pi\,I^3\,w_0^6} + \text{etc.}\right)$$

S_1 is the area in *Fig. 3* included between the curve and the line $N\,R$, areas below that line being reckoned as negative. S_2 is twice the statical moment of the area about $N\,R$, all areas being considered as having a positive moment. S_3 is three times the second moment, or "moment of inertia" of the area about $N\,R$, the moment of all areas below $N\,R$ being reckoned negatively; similarly for S_4, etc. These quantities can be determined most easily by the integraph; in any case it is best to take the parts of the curve above

the line separately from those below, adding with the proper signs afterwards.

The terms in S in the last equation are all small, and decrease in magnitude very rapidly. In fact, if k is the coefficient of unsteadiness, the terms in S_1, S_2 and S_3 are less than $\frac{1}{2}k$, $\frac{3}{8}k^2$, and $\frac{5}{16}k^3$, respectively, particularly so in the case of S_1 and S_3. To find w'_0, dropping the terms in S, we find $w_0 = w_a$. Substituting this for w_0 in the neglected terms, solve again for w_0, repeating as often as necessary.

We have thus found w_0, and hence w for every crank position. We are accordingly able to make a first correction for the inaccuracy in the "exact" method, already mentioned; for in obtaining the energy of the reciprocating parts, or the force necessary to accelerate them, we are able to use a first approximation to their true velocities and accelerations, instead of taking values based on a uniform crank speed. The curve in *Fig. 3* can then be determined anew, and further approximations made as often as desired.

It is not claimed that the last discussion given is easy of application, or, indeed, useful practically, but it completes the solution of the speed variations.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For 1896.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1896:

MEMBERS.

Members at the close of 1895	1,905	
Number of new members elected who have paid their dues in 1896	84	
		1,989
Lost by death, resignation and non-payment of dues,		122
Total membership at the end of 1896		1,867

FINANCIAL STATEMENT.

Balance on hand, January 1, 1896		$17 13
Receipts:		
Receipts from members, annual	$6,364 00	
Receipts from members, life	200 00	
Income from Endowment Funds in hands of the Board of Trustees	1,886 69	
Income from Bloomfield H. Moore Fund	382 24	
Income from Memorial Library Fund	30 73	
Interest on a part of the investment of New Building Fund	340 00	
Interest on B. H. Bartol Fund	50 00	
Interest on investments of Institute's funds	611 66	
Temporary loan	3,000 00	
Cash from subscriptions to, and sales of, the *Journal*, from fees for drawing school, and from other sources	4,864 25	
		17,729 57
		$17,746 70
Payments:		
Committee on Library	$1,045 79	
Bloomfield H. Moore Fund expenditures	407 46	
Memorial Library Fund expenditures	56 00	
Committee on Instruction	983 45	
Curators	1,927 63	
Insurances	541 04	
Salaries and wages	4,623 75	
Temporary loan	500 00	
Interest on temporary loan	450 39	
Life membership fees handed over to the Trustees under amended By-Laws	300 00	
Dues and entrance fees of non-resident members handed over to Trustees for *Journal* endowment	118 00	
Other expenditures	6,596 20	
		$17,549 71
Balance on hand, December 31, 1896		$196 99

ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1896, consist of the following:

(In the hands of the Institute.)

Bloomfield H. Moore Memorial Fund	$15,000 00	
Memorial Library Fund	1,000 00	
B. H. Bartol Fund	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894 .	1,755 00	
		$18,755 00

(In the hands of Elliott Cresson Trustees.)

The Elliott-Cresson Medal Fund (approximate) .		4,500 00

(In the hands of the Board of Trustees of the Franklin Institute.)

The legacy of George S. Pepper	$35,687 50	
The legacy of Eugene Nugent	1,000 00	
The Edward Longstreth Medal Fund	1,000 00	
The donation of an unknown friend	5 00	
The donation of Sigmund Riefler	20 00	
Life membership fund since October 1, 1894 . .	750 00	
Journal Endowment Fund	138 00	
By will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about $50 or more per year, equivalent to a capital sum of	1,000 00	39,600 50
Total		$62,855 50

An increase in 1896 of $438.00.

During the ten years, from 1886 to 1896, the permanent endowment funds have grown from $11,000 to $62,855.50.

LIBRARY.

The details of the operations of the library appear elsewhere in the Committee's Annual Report.

As regards additions, the exhibit for the year is not as favorable as that of the several preceding years, but substantial progress has been made in the work of cataloguing, the benefits of which will be permanent, and considerable additions have been made by devoting a large proportion of the committee's appropriation to the binding of periodicals.

The comparatively poor exhibit of this branch of the Institute's work, it should be said in justice to the Committee on Library, is due to the failure to collect the interest on a portion of the B. H. Moore Fund. There is good reason, however, to believe that (through the intervention of the Solicitor of the Institute) the arrearages of interest will be fully collected during the present year, and that the library exhibit for the year 1897 will be a marked improvement over that of 1896.

The Board, at the suggestion of the Committee on Library, has added to the precautions to protect the library from danger of fire, by bricking up the

back windows on the second and third floors, except in the Secretary's office and the Board room, and tinning the doors and windows.

THE JOURNAL.

The financial statement of the *Journal* for the year 1896 is not as favorable as could be desired, the prevailing depression in business having been felt severely in its operations. This has manifested itself very clearly in the falling off in the sales of sets and extra copies, and also in its receipts from advertisements. As a consequence, the committee reports for the year a small deficit. The prospects for the new year, however, are most encouraging, and with the advent of the business activity, which is hopefully anticipated, the deficit should be more than covered during the year 1897. The Board wishes to express its high appreciation of the manner in which the editorial branch of the *Journal* has been conducted, and of the sound discretion with which its business affairs have been managed by the Committee on Publications.

COMMITTEE ON SCIENCE AND THE ARTS.

The work of this Committee exhibits a degree of activity which compares favorably with that of recent years, and a distinct improvement in respect of its internal organization. The efficiency of the Committee is believed to be greater than at any previous period of its existence, and the character of its work reflects credit upon the Institute.

The details of this Committee's operations appear in its annual report.

INSTRUCTION.

The lecture courses arranged by professors of the Institute, in co-operation with the Committee on Instruction, have fully maintained the high character for excellence which has distinguished them for many years. Many of these lectures are published in the *Journal* and contribute largely to the value and interest of its pages. The Board would, therefore, recommend that the thanks of the Institute be voted to its professors and to the lecturers for their services.

The Board regrets to be obliged to note a falling off in the number of pupils attending the drawing school; but believes that this is fully accounted for by the continued business depression. With the removal of the cause, the patronage of the school should correspondingly improve. With the character of the work accomplished in the school, the Board expresses its cordial approbation.

The branch school at Germantown Junction, established in 1894, has enjoyed a steady growth, and is now self-supporting.

SECTIONS.

The Chemical and Electrical Sections make a satisfactory exhibit of work accomplished during the past year. The annual reports of these Sections are herewith transmitted.

EXHIBITIONS.

The Board has been duly impressed with the importance of seizing the first favorable opportunity that should present itself for the holding of an exhibition, but, until quite recently, the continued business depression and the necessity of providing a special building for such purpose have appeared to the Board to be circumstances which would render the financial outcome of an exhibition gravely questionable. At the present time it is gratifying to the Board to be able to state that the outlook for an enterprise of this kind is much more favorable, and the Board believes it will be in a position to carry into effect the project of an exhibition, to be devoted to the textile industries, during the year 1897. The action of the Board upon the preliminary report of its Committee on Exhibitions will give the members of the Institute all the facts bearing on this important undertaking.

GENERAL REMARKS.

The Board has, a number of times, in previous years, dwelt upon the wants of the Institute and of its valuable library, as to an enlarged fire-proof building and the accumulation of an ample maintenance fund to be vested in the hands of the Trustees, the income from the same to be applied to the maintenance and advancement of the Institute work.

The Institute has been operated upon an exceedingly economical basis; and the expenditures for maintenance cannot be further reduced without seriously crippling its usefulness.

The imperative need of a larger income must be evident to any one who will examine the annual reports of the Board for some years back.

A new Standing Committee on Endowment was appointed recently by the Board, to make another effort for the raising of a maintenance fund, and it is hoped that its labors may meet with some success. One hundred thousand dollars would do very much towards relieving the Institute of the difficulties connected with its annual expenses. At the same time an increase of the membership, especially of life members, the receipts from which are added to the permanent endowment fund, would substantially aid the cause. There ought to be sufficient interest in the Franklin Institute, among the manufacturers of this great city, to enable this committee to make a success of its undertaking.

By order of the Board.

JOS. M. WILSON,
President.

NOTES AND COMMENTS.*

ALUMINUM ALLOYS.

ALUMINUM AND OTHER METALS.—With the exception of lead, antimony and mercury, aluminum unites readily with all metals, and many useful alloys of aluminum with other metals have been discovered within the last few years. The useful alloys of aluminum so far found have been largely in two groups, the one of aluminum with not more than 15 per cent. of other metals, and the other of metals containing not over 15 per cent. aluminum; in the one case, the metals imparting hardness and other useful qualities to the aluminum, and in the other the aluminum giving useful qualities to the metals with which it is alloyed.

More or less useful alloys have been made of aluminum with copper, chromium, tungsten, titanium, molybdenum, zinc, bismuth, nickel, cadmium, magnesium, manganese and tin, these alloys all being harder than pure aluminum; but it is by combination of these metals, with perhaps additions of lead and antimony, that alloys of most value have so far been discovered. Some are with additions of only 1 to 2 per cent. aluminum.

ALUMINUM AND TIN.—Tin has been alloyed with aluminum in proportions of from 1 to 15 per cent. of tin, giving added strength and rigidity to heavy castings, as well as sharpness of outline, with a decrease in the shrinkage of the metal. The alloys of aluminum and tin are rather brittle, however, and while small proportions of tin in certain casting alloys have been advantageously used to decrease the shrinkage, on account of the comparative cost and brittleness of the tin alloys, they are not generally used. Sometimes phosphor-tin is used to give additional hardness, together with good soldering properties, to aluminum alloys.

ALUMINUM AND NICKEL.—Nickel is one of the favorite hardeners used in alloying aluminum. In proportions of from 7 to 10 per cent. of nickel and the rest aluminum, the best casting metal is produced for purposes where toughness, combined with hardness and good casting qualities, is desired. "Nickel-aluminum" has become a trade name. Several new nickel and aluminum alloys for jewelers and other special work have been made. Two of these are: (1) 20 parts nickel and 8 parts aluminum; (2) 40 parts nickel, 10 parts silver, 30 parts aluminum, and 20 parts tin.

ALUMINUM AND MANGANESE.—Manganese is one of the best hardeners of aluminum; it can be cheaply added in aluminum casting metal by means of the rich alloys of ferro-manganese, and for rolling purposes, by adding the pure black oxide of manganese to the electrolytic bath in which the aluminum is produced. The alloys of manganese give special rigidity and hardness to aluminum; in combination with copper and nickel, one of the best hardening alloys of aluminum yet produced has been obtained.

* From the Secretary's monthly reports.

ALUMINUM AND TUNGSTEN.—The alloys of aluminum and tungsten have for the past few years been especially popular for rolled sheets and plates, to be afterwards spun. Under the trade name of "Wolfram-aluminum," the metal has been largely used for military equipments. The alloys of aluminum and tungsten can be advantageously used, with the addition of copper, and also with the triple hardeners, tungsten, copper and iron; or tungsten, copper and manganese; or as usually made, the aluminum is hardened with some copper; tungstate of sodium and ferro-manganese are added to the reducing bath, making an alloy of aluminum, copper, tungsten, manganese and iron.

ALUMINUM AND CHROMIUM.—Chromium, though rather expensive, is an especially advantageous hardener of aluminum. Aluminum hardened with chromium seems to retain its hardness, after annealing or being subjected to heat, better than almost any other of the alloys.

ALUMINUM AND TITANIUM.—Titanium alloys of aluminum, although hard to manufacture uniformly homogeneous, have greater spring and resilience than most other aluminum alloys. Alloys of titanium, chromium and copper, together with aluminum, give some of the hardest and toughest light alloys yet produced.

ALUMINUM AND ZINC.—Zinc is used as a cheap and very efficient hardener in aluminum castings, for such purposes as sewing-machine frames, etc. Proportions up to 30 per cent. of zinc with aluminum are successfully used. An alloy of about 15 per cent. zinc, 2 per cent. tin, 2 per cent. copper, ½ per cent. each of manganese and iron, and 80 per cent. aluminum, has special advantages.

ALUMINUM AND ANTIMONY.—These metals unite with difficulty, and only in bearing metals of the class of Babbitt metals have any useful alloys as yet been discovered.

ALUMINUM AND LEAD.—These metals unite with great difficulty, and no useful alloys have yet been discovered.

ALUMINUM AND COBALT.—This metal also acts, with about an equal amount of copper, as a specially good alloy for hardening aluminum.

The following are two cobalt and aluminum alloys used for special purposes: Sixty parts cobalt, 10 parts aluminum, 40 parts copper. Thirty-five parts cobalt, 25 parts aluminum, 10 parts iron, 30 parts copper.

GOLD AND ALUMINUM.—Prof. W. C. Roberts-Austen has discovered a beautiful alloy, composed of 78 parts gold and 22 parts aluminum, which has a rich purple color.

ALUMINUM AND CADMIUM.—These metals have been alloyed to produce a solder for aluminum, which seems to give good results. Cadmium does not appear to act appreciably as a hardener for aluminum, as do almost all other metals.

ALUMINUM AND BISMUTH.—These two metals combine easily, the alloys being very fusible, as might be expected of alloys with bismuth. They remain unchanged in the air at ordinary temperatures, but oxidize rapidly when melted. Bismuth makes aluminum very brittle. No valuable alloys of these two metals have as yet been discovered.

ALUMINUM AND VANADIUM.—Vanadium is a good hardener of aluminum, and can readily be alloyed with it, due to its presence in some of the bauxites that are native aluminum ores.—*Aluminum World.*

SCIENTIFIC BREVITIES.

From the *Scientific American*, we learn that M. Raoul Pictet, who has done much original chemical work at low temperatures, suggests that by making use of *low temperatures* syntheses may be effected which would be otherwise impossible. In many chemical operations the heat generated so raises the general temperature of the bodies acted upon that all control over the combination is lost. At very low temperatures, however, all chemical action ceases. By choosing the right temperature, therefore, reactions between substances may be made to take place as slowly as desired. By this means M. Pictet has effected combinations that are impossible at ordinary temperatures.

Experiments show that a *light of 1 candle-power* is plainly visible at 1 mile, and one of 3 candle-power at 2 miles. A 10 candle-power light was seen with a binocular at 4 miles, one of 29 at 5 miles, though faintly, and one of 33 candles at the same distance without difficulty. On an exceptionally clear night a white light of 3·2 candle-power can be distinguished at 3 miles, one of 5·6 at 4 and one of 12 at 5 miles.

M. Moissan has found that when *acetylene* is allowed to impinge upon pyrophoric iron, which has been reduced by hydrogen at the lowest possible temperature, the gas is decomposed with incandescence into its constituents. At the same time condensation takes place, and a liquid hydrocarbon, rich in benzine, is produced. The same result is obtained if pyrophoric nickel or cobalt is substituted for the iron. No gaseous compound of either metal is obtained, and he concludes that the decomposition is due to physical causes.

The same author, who has lately prepared *pure uranium*, states that it is whiter in color than iron, can be filed with ease and does not scratch glass. If very finely divided, it decomposes water at the ordinary temperature.

Kozlowski, of Berlin, has introduced *double glass globes for gas lamps*, which contain in the annular space a very dilute aqueous solution of copper sulphate, to which a trace of ammonia has been added. The purpose of this improvement is to cut off the heat rays and to give the light a slight tinge of blue.

ALUMINUM MANUFACTURE IN EUROPE.*

The first works on a commercial scale in Europe—and, indeed, in the world—for the manufacture of aluminum were located in France. From the early commercial work of Deville, at Javel, under the auspices of Emperor Napoleon III, and of Charles and Alexander Tissier, at Rouen, in 1854–55 (who sold their metal at from $2 to $4 per ounce), the Société Anonyme de l'Aluminium, for working and selling aluminum, came into existence with works for making the metal, first at Glaciére, then at Nanterre and later at the chemical works of H. Merle & Co. at Salindres, where, for many years under their proprietorship, and later of Pechiney & Co., the manufacture of aluminum was successfully conducted.

In their first successful work cryolite (the double fluoride of sodium and aluminum) was used as the ore from which to reduce the metal, and later—and more efficiently—chloride of aluminum (Al_2Cl_6) was used as the salt of the metal from which to reduce it by the means of sodium. This firm produced some of the best aluminum that has ever been put upon the market, and earned for the metal praises for properties which later experience with inferior and more impure metal has often not substantiated, to the serious retarding of the introduction of the metal in the arts. Too much praise cannot be bestowed upon these early manufacturers of the metal, who, for more than thirty years from the year 1857, were not only pioneers, but practically were alone in the field. These works enjoyed a practical monopoly of the aluminum business of the world for more than twenty-five years, although there were unsuccessful business enterprises started in England, the first, in 1859, by C. H. Gerhart, at Battersea, a suburb of London, which only ran for a short time; and later, in 1860, by Bell Brothers, at Newcastle-on-Tyne, who made aluminum in a desultory way up to the year 1874.

In 1882 the selling price of aluminum, which had been reduced to about $12 to $14 per pound, was further lowered by the process of an Englishman named Webster, who started a company called the Webster Aluminum Company. Mr. Webster's improvements consisted in a cheaper production of aluminum chloride, used as the salt from which the metal was best reduced by the sodium process. The business of this company was further strengthened by the purchase of the patented process of H. Y. Castner for making the reducing agent, sodium, by an improvement by which a more intimate contact is effected of the carbon used as a reducing agent of the sodium from molten caustic soda. This company developed in June, 1887, into the Aluminum Company, Limited, with a share capital of £400,000, and put up expensive works at Oldbury, near Birmingham, England, for making aluminum chloride, metallic sodium, and from them, metallic aluminum. Among the shareholders of this company were some of the best chemists and metallurgists, as well as some of the most prominent politicians, of Great Britain.

Early in the year 1888, another rival company to the Aluminum Company, Limited, was started at Wallsend, a suburb of Newcastle-on-Tyne, to

* From "The Mineral Resources of the United States," 1895. Dr. David T. Day. Washington, D. C.

work the process of Carl Netto. This process consisted in using molten cryolite as the salt from which to reduce the aluminum, the metallic sodium being made in a furnace by the trickling of molten caustic soda over incandescent coke. Soon after getting into operation, these two companies unfortunately got into legal complications regarding their respective patent rights, and the curious spectacle was presented of these two large and financially strong companies fighting over the patent rights to a process that was destined to prove, before the settlement of the suit, uneconomical as compared with the Hall electrolytic process, that was even at that time being successfully developed in Pittsburgh, Pa. Both of these companies, in the year 1890, stopped the manufacture of aluminum by the modifications of the old Deville process of reduction by means of metallic sodium. Early in the year 1891, the firm of Pechiney & Co. also ceased operations in the manufacture of aluminum; for by this time the selling price of aluminum had been reduced to $1.50 per pound—a rate far below the cost of manufacture of aluminum by the sodium process.

In August, 1891, the selling price was again reduced to 50 cents per pound. The European price for pure aluminum fell, to meet the American competition, to the following prices:

EUROPEAN PRICES OF ALUMINUM.

	Wholesale Price per Pound.	*Retail Price per Pound.*
September 1, 1890, to March, 1891	$1 67	$1 83
March to July 20, 1891	1 32	1 45
July 20 to October 1, 1891	78	88
October, 1891	70	88
November, 1891, to July, 1893	55	66

This rate of 50 cents per pound was far lower than it could be hoped that any sodium reducing process for the manufacture of aluminum could attain, and they all forthwith quit the business, although the meritorious Castner process of manufacturing sodium was developed by the Aluminum Company, Limited, within the next three years to the rate of about 25 cents per pound, that Company having achieved financial success in the manufacture and sale of metallic sodium made by the Castner electrolytic process at Oldbury, England.

Ludwig Grabau, of Hanover, Germany, in 1889, devised processes for making cheaply fluoride of aluminum from kaolin by means of decomposition with sulphuric and hydrofluoric acids; also pure and cheap metallic sodium by the electrolysis of fused common salt, and made some very pure aluminum in 1890. His work was also one of those ruthlessly cut short by the drop in price to 50 cents per pound.

There were several poorly-devised processes, in which the use of an electric current had been called into service, that were as well "given their quietus" by the drop in price to 50 cents per pound for aluminum in 1891. Among these were the following:

(1) Aluminum and Magnesium Fabrik, at Hemelingen, near Bremen. This company at first, from 1884 to 1887, used the process of Grätzel, who

suggested the electrolysis of the chloride or fluoride of aluminum, using compound anodes of part carbon and part alumina. The process was a failure because of the polarization around and excessive wear of the anodes, and because of the non-continuity of the process, as well as because of the expense of the aluminum halogen salts used as the source of the decomposition by the electrolytic action. This company later (1888–1890) used a modification of the Devill sodium process, under the direction of their manager, Herr Saarburger.

(2) The process of Dr. Edward Kleiner, of Zurich, Switzerland, patented in England early in the year 1886, and based on the electrolysis of cryolite, which was electrolyzed after being first melted by the aid of the electric current, as had been first suggested by the work of Sir Humphry Davy and later was published in many forms during the interim between his day and the time when cheap and efficient electrical generators made such a process as Hall's a practicable undertaking. The Kleiner process was started at Hope Mills, Tyddesley, Lancashire, England, and failed, like its predecessor, the Grätzel process, for similar reasons. Its last hopes as a successful process, indeed, waned with the reduction of price to $1.50 per pound; in 1889. The electrical plant of the Kleiner works was purchased by the Pittsburgh Reduction Company, to be used in working its foreign patents.

(3) The process of Adolph Minet, which consisted in the electrolysis of a molten bath of fluoride of aluminum, together with the chloride of sodium, fed by the addition of fresh aluminum fluoride and alumina. From 1888 to 1890 this process was experimented on at Creil, in France, and in 1890 was started on a larger scale at St. Michel, using a water-power of the Vaillorette, a stream running into the Arc River, in High Savoy. This process was worked by the Bernard Brothers, of Paris, who lost money upon the unsuccessful working of the process. Their plant, like that of Kleiner, has since been sold to a firm working under the Hall patents.

(4) The Hérault process for manufacture of aluminum alloys, first put into practical operation on July 30, 1888, at the works of the Société Métallurgique Suisse at the Falls of the Rhine, Neuhausen, Switzerland. In this process alumina is reduced in the presence of carbon and a cloaking metal, like copper or iron, to alloy with the reduced aluminum, by means of the intense heat produced in a powerful electric arc. The Hérault alloy process was abandoned upon the advent of the 50-cent rate for aluminum, in works that had been in operation under the proprietorship of a stock company (the Aluminium-Industrie-Actien-Gesellschaft), at Neuhausen, Switzerland, and at Froges (Isère), in France, as well as at Boonton, in the State of New Jersey.

The Aluminium-Industrie-Actien-Gesellschaft, formed with a share capital of 10,000,000 marks, by the uniting of the Société Électro-Métallurgique Suisse and the Allgemeine Electricität Gesellschaft, of Berlin, in November, 1888, purchased the Hérault continental patents and continued the work of manufacturing aluminum at Neuhausen. This new company soon found that the aluminum alloys made by their Hérault alloy process, which was not essentially an electrolytic process, were superseded in the world's market by

the pure aluminum made by the electrolytic process. It consequently gave up its more expensive alloy furnaces early in the year 1890, after having experimented with the pure aluminum process for some months, and devoted its attention to producing pure aluminum. From the year 1891 it has manufactured almost exclusively pure aluminum. Its present plant —which, by the way, is just at present considerably curtailed in its output of aluminum, on account of going into the manufacture of carbide of calcium with a portion of the available water-power—is limited to the taking from the river Rhine at the Rhine Falls, Neuhausen, of 20 cubic meters of water, equivalent to 700 cubic feet per second, which is conducted through steel penstocks to a fall of 20 meters, developing at a maximum about 5,500 effective mechanical horse-power, which is utilized in a manner to obtain about 3,000 horse-power in electrical current. The plant now consists of one 300 horse-power turbine, two 600 horse-power turbines, and five 610 horse-power turbines, of the Jonval type, one of the turbines being kept in reserve. The turbines have vertical shafts, and each actuates above it a generator of 7,500 ampères at a tension of 55 volts, or 553 electrical horse-power. With this plant running at full time, an output of between 3,000 and 4,000 pounds per day has been produced since the middle of the year 1893. This company has also secured further water-power rights by means of a canal and expensive tunnel, which is proposed to be driven later, when business will warrant, lower down at the Höllenhaken Rapids, Rheinfelden, on the Rhine, near Basle, where it is proposed to erect a plant having 20,000 horse-power capacity. The company has also secured another water-power right at or near Salzburg, Austria.

Following the parent company, the Aluminium-Industrie-Actien-Gesellschaft, the Société Électro-Métallurgique Française, which had established works at Froges (Isère) to manufacture aluminum alloys by the Hérault process early in 1889, soon gave up its alloy business, and in 1891 commenced to sell pure aluminum made by the electrolytic process of dissolving alumina in a molten bath of the fluoride of aluminum together with the fluoride of some metal or metals more electro-positive than aluminum, passing a direct electric current through the bath, and producing aluminum by the electrolysis of the alumina thus dissolved. Its plant at Froges was abandoned in 1893, and a much larger one at La Praz, on the river Arc, in Savoy, was established in 1894, designed to make only pure aluminum. This plant consists of two turbines, each running a generator of about 1,500 electrical horse-power, and its capacity is about 3,000 pounds of aluminum per day.

In the "survival of the fittest," with the lowered selling price of the metal, it will be seen, from the above hasty sketch of the history of the development of aluminum, that a report upon the present state of the art of aluminum manufacture in the years 1893, 1894 and 1895 would have shown in manufacturing operation in Europe only the works of the Aluminium-Industrie-Actien-Gesellschaft, at Neuhausen, Switzerland; the works of the Société Électro-Metallurgique Française, whose works during this period were removed from Froges (Isère) to La Praz, near Modane, on the river Arc, in Savoy, and the works at St. Michel, which, during this period, were

transferred from the hands of Bernard Brothers, who had been working the Minet process, to the Société Industrielle de l'Aluminium, a company which had bought the French patents of Hall from the Pittsburgh Reduction Company. These establishments, with the Pittsburgh Reduction Company in America, with works at New Kensington, Westmoreland County, Pa., near Pittsburgh, and at Niagara Falls, N. Y., were the only ones in the world that were in commercial operation during this period.

So far in the development of the metallurgy of aluminum, France, England, Germany, Switzerland and the United States have been the only countries of the world dividing the honors. In the future the countries having good water-powers will, undoubtedly, compete for the world's trade; and already, as before referred to, the Aluminium-Industrie-Actien-Gesellschaft has secured, in addition to another power on the Rhine, near Basle, Switzerland, a water-power in Austria for a future development of works. In Russia there are several large landed interests with water-powers, the advantages of which are being considered for the manufacture of aluminum. In Norway and Sweden there are also good water-powers which the new developments in electro-metallurgy are bringing into favorable consideration. A plant in Norway, at Sarpsfos, has been definitely decided upon. This plant has a capacity of 10,000 horse-power steadily during the entire year, the fall of the water, which it is proposed to utilize, being about 80 feet. There is a very large volume of water that can be utilized. This plant will probably not be in operation before the year 1898.

The disadvantages of most of the European water-powers that would seem to be in other ways available are their periods of low water in the winter and early spring season, when the snows of the mountain glaciers which feed their head waters, where water-powers are situated, are frozen up. Owing to the comparative slowness of operation of the present successful electrolytic process of manufacture of aluminum, continuity of operation seems to be an almost necessary prerequisite to economical manufacture, and a plant that would be forced to lie idle or work at a greatly reduced output for three months out of the twelve will undoubtedly be so seriously handicapped as to be unable to compete for the business of the future.

As to methods of manufacture, all the aluminum now being made in the world is practically made by the general process of the electrolytic decomposition of alumina, dissolved in a molten flux consisting of the fluoride of aluminum, together with the fluorides of a metal or metals more electro-positive than aluminum; the idea being to use a flux which dissolves the ore with the most facility, remains molten the longest, is least subject to decomposition, allows the best circulation around the anodes, and is the easiest to manage continuously without caking up.

Hérault suggested—and in his patents only mentions—cryolite, a specific mineral, composed of aluminum fluoride, 40·25 per cent.; sodium fluoride, 59·75 per cent. Hall preferred, and in his patents, besides his broad claim, suggests, several mixtures containing much larger proportions of aluminum fluoride, with the additions of the fluorides of other electro-positive metals,

notably the fluoride of calcium, as giving better results than with the use of cryolite alone as a flux.

The Pittsburgh Reduction Company, in its experience, has found some of these mixtures to give not only a greater yield per unit of electrical current, but a considerably less cost in operating, due to the freedom from caking from the products of the decomposition of the bath; and, more important still, has found that these special mixtures of the electrolyte have produced metal much freer from the impurities of sodium, carbon and occluded gases than it would be possible to obtain with cryolite alone used as the flux. The examination for these impurities (by the French chemist, Moissan), of the metal made in Europe, in comparison with that made by the Pittsburgh Reduction Company, has confirmed this fact.

Bauxite has become recognized as the best native ore of aluminum, and, as the purification of its contained alumina from silica, oxide of iron and titanic acid has shown that the silica is the *bête noir* of the operation, the location of bauxites rich in alumina, and at the same time low in contained silica, is an important factor to the manufacturer of aluminum. So far, the red bauxite of the Department of Var, in Southern France, has been the great and, in fact, the only large commercial source of such ore in Europe. The Styrian Alps have furnished some bauxite low in silica, and late reports have been that there had been some large deposits of such ore recently opened up; but it is a fact that, up to the year 1896, no large commercial shipments of it have been made, and that the operators in Southern France have furnished, from the district of the Var, practically all of the bauxite ore used in the manufacture of aluminum in Europe, with the exception of some few shipments of bauxite from America. The bauxites low in silica, in the Var in France and in similar large deposits in America, are all at the surface, with no superincumbent strata, except a few feet of surface earth and clay, to be stripped, and the mining is all of an open quarrying operation upon faces of the ore from 20 to 50 feet in thickness.

The British Aluminium Company, Limited, is now building a works at Foyers Falls, in Scotland, to manufacture aluminum. The water is taken from the river-bed, about ¾ mile above the falls, and is carried through a circular, brick-lined tunnel, 9 feet in diameter, to the slope of a hill, at the base of which, toward Loch Ness, the power-house of the proposed works is situated. The water is to be conveyed from the tunnel to a basin, from which five lines of cast-iron pipe (28½ inches internal diameter) convey it down the slope of the hill to the power-house, 45 feet wide, 90 feet long and 26 feet high, on posts, where each pipe is to feed a turbine water-wheel at the very considerable head of about 325 feet. This plant is estimated to have a maximum of about 4,000 horse-power when the high-water level in the tunnel can be maintained. The British Aluminium Company, Limited, has purchased the water rights to a very large tract of land in the hills above its present source of supply, and purposes increasing the natural drainage basin of its watershed and increasing the capacity of the locks which form its storage reservoirs. The British Aluminium Company, Limited, up to this writing (February, 1896), has not manufactured any aluminum, but

has acted as British selling agents for the Aluminium-Industrie-Actien-Gesellschaft, whose patents for the manufacture of aluminum in Great Britain, as well as those of the Cowles Company, it has bought. This plant and another at Sarpsfos, in Norway, are the only new ones now in actual progress of erection for the manufacture of aluminum that are known to the public at this time.

ELECTROLYTIC COPPER REFINING.

The annual report of the Anaconda copper mine, just presented, is very interesting, from the fact that electrolysis plays so large a part in the work. This Montana property has exceeded 100,000,000 pounds of copper per year, while the great Calumet and Hecla mine in the Lake Superior region shows up with but 90,000,000. On total receipts of $17,000,000, the Anaconda property shows a profit balance for the year of about $4,250,000, and is paying 10 per cent. on its present capital of $30,000,000. It appears that the refining plant can take care of 6,000,000 pounds of copper per month or 3,000 tons. On a basis of 200 tons of refined copper per day, the copper would yield 350,000 ounces of silver per month and 1,500 ounces of gold; and it is noteworthy that the Anaconda property, in addition to its 107,000,000 pounds of copper, is given credit in the report for 5,308,955 ounces of silver and 18,300 ounces of gold, which would represent about $3,500,000.—*Eng. & Min'g Jour.*

PRESENT CONDITION OF THE POWER UTILIZATION OF NIAGARA.

Mr. W. B. Rankine, secretary to the Niagara Power Company, contributes an interesting paper to the *Electrical Engineer*, from which we glean the following abstract:

The plans of the Cataract Construction Company and the works of the Niagara Falls Power Company are so far completed that delivery of power to customers in Buffalo has been successfully instituted, and the calls for power under contracts actually executed (and in excess of the present capacity of the works) will provide annual rentals which, with contracts in negotiation, represent a total income from that source falling not far below half a million dollars.

The present electrical installation comprises three dynamos, each of 5,000 electrical horse-power, of which one should be kept as a reserve; but the demand has made such reservation impossible, and the contracts already made for 15,825 electrical horse-power exceed not only the prudent, but the actual capacity of these works, which require immediate extension, with every prospect of prompt and profitable employment.

The proposed extension involves doubling the present capacity of the transmission line to Buffalo, which, already in successful operation, is delivering 1,000 electrical horse-power; the extension of the wheel-pit for its full length, so as to have capacity in all for ten 5,000 horse-power turbines and

dynamos; the installation of seven 5,000 horse-power turbines and dynamos, in addition to the three now in operation; and the extension of the power-house to cover the new installation. The work of such an extension of the wheel-pit is about one-third completed; the right of way from Niagara Falls to Buffalo is complete; the pole line already erected has a pole and cross-arm capacity for 20,000 electrical horse-power, with copper conductors in place for 5,000 electrical horse-power. Upon definite proposals already received, the entire installation above described can be accomplished within the year 1897.

As a concrete presentation of the facts, I will add a list of the contracts for power up to election day, 1896. No more eloquent statement as to results achieved could be given, were I to fill a volume of your journal:

	Horse-Power.
HYDRAULIC POWER.	
Niagara Falls Paper Company	7,200
ELECTRIC POWER.	
Pittsburgh Reduction Company (aluminum)	3,050
The Carborundum Company (carborundum)	1,000
Acetylene Light, Heat and Power Company (calcium carbide)	1,075
Buffalo and Niagara Falls Electric Light and Power Company (local lighting)	500
Walton Ferguson (chlorate of potash)	500
Niagara Electro-Chemical Company (peroxide of sodium)	400
Buffalo and Niagara Falls Electric Railway (local railway)	250
Niagara Falls and South Buffalo Railway Company (local railway)	250
(All from October 1, 1896.)	
Buffalo Street Railway Company (22-mile transmission)	1,000
(From November 15, 1896.)	
Acetylene Light, Heat and Power Company.	
(From February 1, 1897)	1,000
(From March 1, 1897)	1,000
(From delivery, say, November 1, 1897)	2,000
Mathieson Alkali Works (soda ash)	
(From June 1, 1897)	2,000
Buffalo Street Railway Company	1,000
Buffalo General Electric Company (lighting)	3,000
(From November 15, 1897.)	
Totals	25,225
SUMMARY.	
Total hydraulic power sold—Niagara	7,200
Total electric power sold—Niagara	13,025
Total electric power sold—Buffalo	5,000
	25,225
ADDITIONAL.	
Albright & Wilson, Limited (electro-chemicals)	400
1896—Grand total	25,625

It will be obvious at a glance that Niagara has already started on its career as a great chemical center, and thus justifies the predictions that the chemical trades would center ultimately around the sources of cheap power.

THE STORAGE BATTERY IN EUROPE.

American street railway companies cannot, as a rule, be accused of want of enterprise, and they have spent large sums of money in experimenting, or what is practically experimenting, on new systems of traction—mostly electrical. Just now, however, in the matter of the storage battery, they are letting others do the experimenting, and are watching carefully the outcome of the activity which is going on in the installation of accumulator cars in Europe. In Hanover, where a combination system of trolley and accumulators is employed, sixty cars have been equipped with batteries and eighty more are to be installed by next spring. The batteries are charged from the trolley line outside the city limits sufficiently to carry the cars without the aid of the trolley within those limits. In Dresden thirty storage battery cars are running and fifteen more are to be put on shortly. Here, also, the cars are run by the trolley outside, and by storage battery inside the city. In Copenhagen eighteen accumulator cars are to be in operation in the beginning of January. The system employed will be entirely storage battery. In Hagen, eight cars on the same system are in operation, and ten more are to be added. In Paris, thirty-five storage battery cars are to be equipped on the lines of the Compagnie du Nord. In Berlin the city government has decided to run on all the lines of the city storage battery cars on the mixed system, the outer lines to be equipped with trolley. The underground conduit has been entirely abandoned, and it is expected that Berlin will soon have in operation from 600 to 700 cars actuated by storage batteries.

CARBORUNDUM PRODUCTION AND USE.

The Carborundum Company reports to the *Engineering and Mining Journal* that its works have produced during the year 1896, in round numbers, 1,191,000 pounds or 595¼ tons of crystalline carborundum. Consideration at the present is given to the production in crystalline form only, but another important industry into which carbide of silicon promises to be a valuable adjunct will naturally increase the usefulness of the material. Some mention has been made of the experiments showing that carborundum can be used, and will, in all probability, take the place of ferro-silicon in the manufacture of steel. Professor Luehrmann, of Germany, recently wrote an article on this subject, indicating that in the use of carborundum there will be in Germany alone, approximately, 2,500 tons consumed annually, provided its cost would not exceed 6 cents per pound. It may be used for this purpose in an amorphous form, and the Carborundum Company is prepared to furnish it at a price slightly under this figure.

Elsewhere in the *Journal* will be found an excellent descriptive paper on the carborundum plant at Niagara Falls, from the pen of Mr. Fitzgerald, chemical engineer of the works.

This industry stands as a conspicuous illustration of the possibilities of the electric furnace as the source of hitherto unknown and valuable products.

W.

BOOK NOTICES.

The Manufacture and Properties of Structural Steel. By Harry Huse Campbell, S.B. New York and London: The Scientific Publishing Company. 1896. 8vo, pp. 397. Price, $4

The above work adds another to the series of admirable metallurgical treatises that have emanated from the press of these publishers.

The author's long experience in the manufacture of steel, as the superintendent of one of the largest steel companies in the United States, and his practical familiarity with the various processes and machinery of the modern steel-maker's art, qualify him unusually well to treat the subject in such a manner as to command the respectful attention of metallurgical engineers.

Although confined, by its title, to structural steel, the author takes into consideration other branches of the steel industry that are closely related to it.

An interesting and valuable portion of the book is that which treats of the subject of establishing a standard for the strength of pure iron, and for the value of each unit of accessory constituents in modifying the strength in the commercial products known as steel, with the object of placing at the command of the steel-maker and steel-user a set of formulæ from which the composition of a metal designed for any special purpose can be computed, or *vice versa.*

The author's investigations on this most important subject are interesting, and his critical remarks on the work of others, notably on the work of Mr. Wm. R. Webster, may be read with instruction by all who wish to keep abreast of the present state of steel metallurgy. The author's comments on this topic will not be encouraging to those who have been hoping that a reliable working formula for representing and determining the strengths of steels would soon be at the command of the maker and user of the products known by this name. Intelligent criticism, however, cannot fail to be beneficial in eliminating errors and exposing the weak points of promising hypotheses.

W.

The Influence of Sea Water on Hydraulic Mortars. Translated from the German of Herr Rud. Dykerhoff, by O. M. Carter, Captain Corps of Engineers U. S. A. Washington: Government Print. 1896.

This pamphlet contains the results of a series of experiments undertaken by Herr R. Dykerhoff, proprietor of extensive cement works, for the purpose of comparing native hydraulic limes and Portland cements with hydraulic lime of Theil and Santorin earth when exposed to the action of sea water.

The details of these experimental tests are given *in extenso*, and the results obtained are believed to contain information not to be obtained elsewhere. The translation is made specially for the information of the officers of the Corps of Engineers, but its value will be duly appreciated by engineers in general.

W.

Resolutions of the Conventions held at Munich, Dresden, Berlin and Vienna, for the purpose of adopting uniform methods for testing construction materials with regard to their mechanical properties. By J. Bauschinger, Professor in the Technical High School, Munich. Translated by O. M. Carter, Captain Corps of Engineers, U. S. A., and E. A. Gieseler, U. S. Assistant Engineer. Washington: Government Print. 1896.

On Tests of Construction Materials. Translations from the French and from the German, by the same. Washington: Government Print. 1896.

These pamphlets, which have been printed primarily for the use of the officers of the Corps of Engineers, will prove of substantial value to the engineering profession at large, as a contribution to the important desideratum of securing uniformity in the methods of testing materials used in construction.

W.

Friction, Lubrication and the Lubricants in Horology. By Wm. T. Lewis, President Philadelphia Horological Society. (Illustrated.) Chicago: Geo. K. Hazlitt & Co. 1896.

The author of this little treatise calls attention in his introductory remarks to the fact that, while elaborate scientific treatises have been written on the mechanical branches of the watchmaker's art, comparatively little attention has been bestowed upon the subject—equally important in its relation to the accurate time-keeping qualities of the mechanism—of the lubrication of the watch or chronometer.

The study of this branch of the art reveals to the uninitiated a highly specialized industry, dealing with a comparatively small number of oils, of which a large proportion are of curious origin.

Mr. Lewis describes and treats of the properties of these products from the standpoint of the watchmaker, in a thoroughly satisfactory way. He describes the methods of testing oils, and gives an account of a number of experiments, undertaken by himself, to determine the relative value of the lubricants used in horology. The work should prove extremely useful to the practical watchmaker. W.

Lessons in Practical Electricity, specially arranged for the use of students of the Electrical Classes at the Spring Garden Institute. By C. Walton Swoope, Instructor in Electrical Engineering. Philadelphia: The Spring Garden Institute. 1896.

This manual has been prepared by the author as a guide for the students in the Electrical Classes of the Spring Garden Institute under the author's direction. It appears, from a careful examination of its scope and character, to be exceedingly well adapted for service in a graded course of instruction for beginners; in fact, we know of no work in the English that is so well suited for the needs of beginners. The method of the work is strictly experimental, and practical exercises, in the form of problems for solution, accompany the text wherever the subject renders them admissible. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, January 20, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 20, 1897.

JOSEPH M. WILSON, President, in the chair.

Present, 118 members and visitors.

Additions to membership since last report, 11.

The Actuary reported the following resolutions passed by the Board of Managers, at its stated meeting, held January 13, 1897.

"*Resolved*, That the President and Secretary of the Franklin Institute be and are hereby authorized to take immediate steps to secure subscriptions to a guarantee fund of at least $25,000, to protect the Institute against pecuniary loss in connection with the holding of an exhibition devoted to the textile industries.

"*Resolved*, That as soon as the minimum amount above-named shall have been subscribed, the Board of Managers shall proceed to make public announcement of the fact that the Institute will hold, in the autumn of 1897, an exhibition devoted to the textile industries, including therein the raw materials, processes, machinery, and the products, and the arts of design in connection with the textile industry, and take immediate steps to carry the undertaking into effect, provided a lease of the building can be obtained on satisfactory terms."

The Secretary submitted the annual reports of the Board of Managers, the several Standing Committees and Sections of the Institute, and the Trustees of the Elliott Cresson Medal Fund, which, on motion, were accepted.

(The annual report of the Board is printed elsewhere in this impression of the *Journal*.)

The judges of the annual election presented their report, whereupon the the President declared the following persons to be elected:

*President**	to serve one year, ...	JOHN BIRKINBINE.
Vice-President	" three years, ...	W. P. TATHAM.
Secretary	" one year, ...	WM. H. WAHL.
Treasurer	" " "	SAMUEL SARTAIN.
Auditors	" three years, ...	W. O. GRIGGS.
	To serve for the unexpired term of Samuel H. Needles, deceased . . .	JOHN H. COOPER.

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* Mr. Joseph M. Wilson declined a renomination.

Managers (to serve three years).

ARTHUR BEARDSLEY, HENRY C. BROLASKY, JAMES CHRISTIE, F. L. GARRISON, H. W. JAYNE, LAWRENCE T. PAUL, HORACE PETTIT.

Committee on Science and the Arts (to serve three years).

WM. M. BARR, H. F. COLVIN, THOS. P. CONARD, SPENCER FULLERTON, JOHN M. HARTMAN, JOHN HAUG, WM. C. HEAD, WM. C. HENDERSON, H. R. HEYL, GEO. A. HOADLEY, LOUIS E. LEVY, D. ANSON PARTRIDGE, TINIUS OLSEN, SAMUEL P. SADTLER, PAUL A. WINAND.

The judges of the election were given a vote of thanks for their services.

On motion of Prof. F. L. Garrison, duly seconded, the meeting, by unanimous vote, adopted the following resolution:

"*Resolved*, That the grateful thanks of the Franklin Institute be and are hereby tendered to its retiring President, Mr. Joseph M. Wilson, in recognition of his faithful attendance as presiding officer at the stated meetings during the ten years of his service as President, for his uniform courtesy and impartiality as a presiding officer, and for his constant and unremitting efforts during this period to further the movement for a new building and to promote the usefulness of the Institute."

The retiring president made an appropriate response in acknowledgment.

A vacancy in the Board of Managers, reported by the Secretary, was filled by the election of Mr. Otto C. Wolf.

Prof. Angelo Heilprin, delegate of the Institute to the Millennial Celebration of the Kingdom of Hungary, gave an oral account of his mission, under the title of "Observations on the Progress of a Nation—Hungary." The speaker's remarks were devoted largely to the municipal improvements exhibited in the city of Buda Pesth, and the engineering improvements of the mouth of the Danube.

The meeting passed a vote of thanks to Prof. Heilprin for his interesting and valuable report.

Mr. A. E. Outerbridge, Jr., made some remarks on the subject of "The Advantages of Mechanical Stoking," with especial reference to the conditions involved in the abatement of the smoke nuisance in cities. The subject was illustrated with the aid of lantern slides showing such devices in operation. Extended references were also made to the substantial reforms that had been realized in Chicago and other cities where soft coal is almost exclusively used, by the adoption of municipal ordinances regulating the operation of steam plants.

Mr. H. C. B. Nitze described and exhibited in operation an improved "Magnetic Ore Separator," devised by Mr. J. Price Wetherill, of Bethlehem, Pa.

Mr. H. R. Heyl exhibited and described an improved safety device for bicycles.

Adjourned. WM. H. WAHL, *Secretary*

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ICE CAVES AND THE CAUSES OF SUBTERRANEAN ICE.*

BY EDWIN SWIFT BALCH, A.B., F.R.G.S.,†
Member of the Institute, ex-President of the Geographical Club of Philadelphia, etc.

I. DESCRIPTIVE AND EXPLANATORY.

Terminology.—The term "ice cave" refers to a rock cavern containing ice. It does not refer to a hole or tunnel, cut by the hand of man into a glacier, such as those one sees at Grindelwald or Chamonix. I make this statement, because on mentioning ice caves in conversation I have repeatedly been asked whether I meant those tunnels. The Germans use a term similar to ours, *Eishöhle*, while the French and Swiss use the word *glacière*, the feminine of

† A lecture delivered before the Franklin Institute, January 4, 1897.

glacier, which they also apply to artificial ice houses, speaking of ice caves as *glacières naturelles*, and of ice houses as *glacières artificielles*. The term *glacière* seems to me the most accurate in use in any language, and, if it were not too late to do so, it would be an advantage to use it, especially as we have adopted the term *glacier* from the same part of the world. In my opinion, the term "ice cave" should especially apply to the hollows in the ice at the lower end of glaciers, whence the glacier waters make their exit. The Hon. George N. Curzon uses the term, apparently in this sense, in a sketch published in the *Geographical Journal* in connection with his recent journey to the Pamirs, and in the account in the same publication of the visit of the English Training Squadron to Spitzbergen, in 1895, the term was applied to a natural tunnel found in a glacier.

Glaciers.—Ice enduring all the year round is found in three principal forms: glaciers, ice gorges and ice caves. Glaciers are formed, to speak in general terms, from the winter snows which have fallen from the skies, and, by their own weight, and melting and regelation, have accumulated into a mass of ice, causing the phenomenon known as a glacier. Glaciers depend, therefore, practically on the annual snowfall and a low temperature for their existence.

Ice Gorges.—Ice gorges or ice gullies show kinship to both glaciers and ice caves. They occur in fissures or ravines, at an altitude below the general snow line of the district, where the winter snow is sufficiently protected from the sun to endure either as snow or ice through the summer months. In some cases the surface ice and snow melts away, while underneath boulders, at the bottom of fissures, ice still remains. For instance, I have found lumps of ice in King's Ravine, on Mount Adams, in the White Mountains, late in September, among the big boulders which form such a trying path for the traveller. In such gullies, however, we have something resembling rather miniature glaciers than ice caves, in that gullies receive the accretion to their ice directly from the winter snows. Some of the reasons for their endurance are similar, however, to those which apply to ice caves, in that they receive little if any of the direct

rays of the sun, and are also scarcely exposed to any hot winds. It is almost a self-evident proposition that the ice in such gullies is formed in the same manner as the ice of glaciers, or the ice on ponds and rivers, by the cold of winter and the melting of the snows; and when ice is found remaining under boulders in such localities, it is simply that the snow water has run to the lowest level and there congealed. For convenience these gullies may be divided into two classes:

(1) The ordinary open ravines, of which a fine example occurs in the Shawangunk Mountains in New York State.

(2) The ice under boulders, such as we find in King's Ravine.

Ice Sheets.—A subterranean ice sheet covered with lava is reported from Mount Etna, and probably similar sheets also occur in Iceland. Sir Charles Lyell accounts for the one on Etna by the explanation that there must have been a great snow bank in existence at the time of an eruption of the volcano, and the lava stream must have flowed over the snow, which, in course of time, turned to solid ice underneath.

Wind-Holes.—In many parts of the world we find what are known as cold-current caves, or blowing holes, or wind-holes. These are pipes or holes, and in general they are found in more or less broken limestone rocks. In most cases a cool air pours forth from them in summer, while the cold air pours into them in winter, the draught being then reversed. In some cases, however, the operation is said to take place in the opposite way. De Saussure made an experiment in connection with the first kind of these holes, showing what is probably the cause of the cooling of the air current. He passed a current of air through a glass tube, an inch in diameter, filled with moistened stones, and found that the air current which entered with a temperature of 22·5° C., came out with a temperature of 18·75° C., that is, with a loss of 3·75° of heat. As in limestone caverns there would generally be moisture on some of the rock surfaces on which air currents would pass, it is doubtless the evaporation from these surfaces which lowers the temperature of the air cur-

rents. These wind-holes do not seem to necessitate the presence of ice. I have examined five of them myself, and in no case was there any ice visible. Whether there was any ice within the mountain I cannot, of course, say. At Seelisberg, on the Lake of Lucerne, the peasants have built little stone houses over the rocks whence these currents issue, and use these houses for keeping their provisions during the heats of summer. In all the wind-holes I have seen the cool air was pouring out.

Ice Caves.—Ice caves differ greatly from ice gullies. The greatest divergence is that there is a roof. This means that the ice is formed directly in the cave itself, and is not, except perhaps near the entrance, solidified snow, but genuine subterranean ice. The roof, while not admitting the winter snow, is, however, a protection against warm summer rains, and, of course, entirely cuts off radiation from the sky. If, therefore, it keeps out some cold, it also acts as a protector against heat. It may be noticed here that there is a strong resemblance between natural ice caves and artificial ice houses, a resemblance implied in their French appellation, *glacière*, and, in fact, it is hardly too much to look on ice caves as natural ice houses.

Kinds of Ice Caves.—Ice caves proper vary greatly in their positions, shapes and sizes. They may be divided into three main kinds:

(1) Those at or near the base of cliffs, entering directly into the mountain with a down slope. This class is found in limestone and in volcanic rocks. Examples: The Kolowratshöhle, Dobsina, Roth in the Eifel.

(2) Those at or near the base of cliffs, where a long passageway exists before the ice cave proper is reached. All I know of in this class are in limestone rock. Examples: Demenyfálva, the Frauenmauer.

(3) Those where a large pit opens into the ground, and the ice cave is found at the bottom opening into the pit. These are in limestone. Examples: Chaux-les-Passavant and la Genollière.

Ice Caves with Wind-Holes.—In two or three cases there are ice caves in connection with wind-holes; that is, there

is first a large ice cave, at the rear of which is a fissure from which a draught comes. One of these is near Cluses in Savoy, and Professor Thury states that along the line of the draught he found the ice in August more melted than elsewhere in the cave. Another of these ice caves with a windhole is in Washington Territory, and is the largest ice cave so far reported in the United States.

Mines and Freezing Wells.—Subterranean ice is also found in certain places in connection with man's handiwork. It is reported as forming in some few mines in Europe and America. In some wells, also, in the New England States, abnormally low temperatures have been observed, and for four or five months of the winter the surface of the water is frozen so thick as to render these wells useless.

Geographical Distribution.—Ice caves proper are found in various parts of Europe, Asia and America, mostly in the smaller ranges or in the outliers of the snowy ranges, generally in limestone and occasionally in basaltic formations. There are a good many in the Jura, a few in Switzerland, a few in the Italian Alps, a number in the Eastern Alps, in Tyrol, Steiermark and Carinthia. There are some in Hungary, several in Russia, one in Iceland, one on the Peak of Teneriffe, several in Siberia, one in Kondooz in Central Asia, one in Japan, and one in Korea. I have heard, so far, of twenty-nine places where subterranean ice is reported as occurring in North America, two of which are in Pennsylvania. Professors Schwalbe and Fugger give lists which mention over 200 places where subterranean ice is said to occur. However, these lists are not claimed by the authors themselves to be accurate.

Dimensions.—The dimensions of ice caves vary greatly. Some are very large, some very small. The measures of the cave at Dobsina, in the Carpathians, are given as follows: Height of roof above ice floor, 10 to 11 meters; length, 120 meters; breadth, 35 to 60 meters; and surface about 4,644 square meters. The Frauenmauer Cave, in Eastern Tyrol, has an ice floor about 50 meters long by about 7 wide. The ice cave near Frain, on the contrary, is so small that one can only crawl in some 2 or 3 meters, and this at the expense

of soiling one's clothing. In fact, ice caves vary in size between great halls and small tunnels, in which one cannot stand up straight.

Size of Entrances.—The entrances of ice caves vary also greatly as to their dimensions. As a rule they are small, that is, about the size of ordinary door-ways; but the entrance to the Schafloch, for instance, is about 10 meters wide by 7 meters high, while the entrance to Roth in the Eifel is not over 1 meter each way.

Drainage.—An important point in all ice caves is the need of some outlet for the surplus water at the lowest point of the cave, as otherwise the cave would soon be entirely filled. As the caves are always in either porous or broken rocks, the necessary drainage takes place through the cracks and fissures in the rocks.

Forms of Ice.—Almost all the forms assumed by underground ice are different from those visible in glacier or iceberg. This is only what should be expected, as the ice is formed under such different conditions from those which obtain overground. There are no séracs or crevasses such as one sees *en route* to the Grand Mulets, for instance. The sharp angles and fractures visible on glaciers are absent. Almost all the lines are rounded. Unique forms of subterranean ice are those produced by the drip from roof or sides, that is, the forms of ice answering to the stalactites and stalagmites of limestone caves. They descend from the roof as icicles or rise from the floor as cones or pyramids. Sometimes the icicles reach to the floor, and, connecting with it, become regular columns; or sometimes columns issue from fissures in the sides in the shape of frozen waterfalls.

At Dobsina the stalactites form grand ice pillars. They are from 8 to 11 meters in height, and from 2 to 3 meters in diameter. In some of the caves, as at Chaux-les-Passavant, the ice stalagmites take nearly the form of cones. There are some seven or eight of them, the tallest of which is at least 6 meters high, with a diameter at the bottom of 5 or 6 meters. Sometimes these cones are hollow, as is the case in a grand one at the Schafloch, some 6 meters or more in height.

The columns issuing from the sides of ice caves, for lack of a better name, I call fissure columns. They seem always to issue from a crack in the rock, and then sometimes stream over the rock. Sometimes they spring out far enough from the rock to be quite away from it. These fissure columns vary from about 2 to 7 meters in height, and at the base almost always spread out fan-shaped. Schwalbe speaks of these columns as "subterranean glaciers." Some are found in almost every ice cave; in one case—the Glacière de Chapuis—they form the special beauty of the cave, as there are some seven or eight of them, each perhaps 5 or 6 meters high, and about 1 meter in diameter, and spreading into fan-shape at their base.

The ice on the bottom of the caves of course takes its shape from the shape and angles of the floor of the caves. If the floor is level or nearly so, we find the ice in the shape of a sheet or floor. If the floor of the cave be sloping the ice will be found on more or less of a slope, sometimes becoming nearly or quite vertical, as an ice slope or ice wall, and distantly resembling the portions of glaciers called an ice fall, with the great difference, however, that there are no crevasses, not even tiny ones.* Holes we sometimes find, as at Haut d'Aviernoz, or runnels, as at the Kolowratshöhle, but these are entirely distinct from crevasses. On these ice walls or ice slopes, there is, in fact, no visible sign of anything that would lead to a suspicion of motion.

The holes, or runnels, just referred to are generally found at the lowest point of the ice floors and are almost certainly cut out by the melting water, to which they act as an exit. In fact, they form the drainage system in the ice. The holes are sometimes very deep. At Haut d'Aviernoz I looked down into one, which must have been many meters deep, and whose sides disappeared in darkness, no bottom being visible.

The drip produces also the exact opposite of cones, in the shape of ice basins. There are two splendid ones in the

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* No observer seems as yet to have looked for any evidences of motion in subterranean ice.

Kolowratshöhle, each cut out in the floor by an extra strong drip from the roof at those spots. Such basins as these are not to be seen on glaciers.

Lakes and pools are to be found in ice caves. At Chaux-les-Passavant a pool of water, perhaps 30 centimeters in depth and 4 or 5 meters in diameter, lay at one place in August on the ice floor. The whole cave was damp and the ice in places decidedly slushy, in fact, all the signs pointed to a heavy thaw going on, and there could be no doubt that the pool was the result of this. In the Glacière de Chapuis, far underground, there are two adjoining caverns, one filled with water, the other with ice.

Again, in at least one case, the Kolowratshöhle, a lake sometimes forms on the ice floor in the spring, freezes over, and then runs off, leaving the marks of its passage in the shape of ice slabs reposing on the solid ice floor, as was the case on my visit to this cave in the middle of July, 1895.

I think there is no doubt that subterranean snow sometimes occurs, probably early in the year. A case of the kind occurring in Central France has been noticed in Monsieur Martel's book, "Les Abimes," and my brother and I, in a visit to the Dobsina cave early in July, before much thaw had set in, found in one spot of the cave a small sheet, perhaps 2 meters each way, of what, to look and touch, was genuine snow. I have little doubt that this was formed by the congealing, during their fall, of drops of water from the roof.

The ice in caves is sometimes found in a form or structure which is, I believe, of rare occurrence above ground. This is when it occurs in the shape known as prismatic ice. If you break off a lump from a column or icicle you will sometimes notice that it breaks into regular prisms. I have seen this prismatic ice a few times only. Browne speaks of it in his book as common. I am not sure that the phenomenon is as yet satisfactorily accounted for; the only thing I feel sure of is that it does not occur in ice of recent formation. Thury speaks of it as a form which is due to some change in ice which has already been formed for some time.

ICE SLOPE, KOLOWRATSHÖHLE.

THE ENTRANCE OF THE KOLOWRATSHÖHLE.

Color Effects.—The color effect of every ice cavern has a certain individuality. At the Kolowratshöhle the ice is beautifully transparent and of a pale ochre-greenish hue; the limestone rocks are streaked with iron, and thus have a reddish hue, while, owing to the entrance admitting plenty of daylight, the effect is only semi-subterranean. At the Schafloch it is the exact opposite of this; the ice is so completely away from daylight that black is the predominating note, the ice itself looking a dark gray. Again, at Chaux-les-Passavant plenty of daylight is admitted; the rocks are a yellowish-brown, while the ice is white and blue. At Dobsina, on the contrary, thanks to the electric light, white is the predominating note, in certain places and corners dulled into grayness by rock or shadow.

II. CAUSE OF THE FORMATION OF ICE.

The cause of the formation of the ice is practically the most intricate thing to understand and explain about ice caves. Numerous explanations have been offered on the subject, and many theories formulated, some of which are absolutely untenable. The great cause, as far as I can see, is simply the cold of winter, which re-forms anew each year the ice which has been destroyed by the heat of the preceding summer. Before elaborating the winter's-cold theory, I wish to mention two or three theories which cannot possibly be accepted in connection with the facts.

Glacial Period.—A suggestion to account for the ice, which seems to occur to many persons when they first hear of ice caves, is that the ice is a remnant of the glacial period. This theory is quite untenable. The great cave of Chaux-les-Passavant was entirely cleared of its ice in 1727 by the Duc de Lévi for the use of the Army of the Saone. In 1743 the ice was formed again. At Szilize, every year, the ice has almost completely disappeared by November, and the cave is free; but in April or May the floor is again covered with ice, and columns and icicles have formed on the roof and sides. At La Genollière, the cave is used by the people of the neighboring chalets through the spring and early summer to help in the operation of butter-making; by the mid-

dle or the end of August it has entirely disappeared, but is found formed afresh every spring. Too many examples of the complete melting away of the ice every year can be cited to permit any doubt on this point; ice caves are not connected with a glacial period.

Salts.—Another favorite suggestion, which cannot stand on an acquaintance with the facts, is that there must be salts in the rocks. An elaborate paper, giving this as the true cause of the ice in Chaux-les-Passavant, was published in 1712, by M. de Billerez, in the proceedings of the French Academy. He stated that the earth in the immediate neighborhood, and especially above the roof of the grotto, was full of nitrous or ammoniacal salts, and he suggested that this salt was disturbed by the heat of summer, and mingled with the water which penetrated by fissures into the cave. His observations have been absolutely disproved, and in no place have any such salts been found. Repeated experiments in letting lumps of cave ice melt in my mouth have convinced me personally that in all cases the water is exceedingly pure and sweet, and there can be no doubt that all, what might be called, chemical causes, must be entirely eliminated as possible cold-producers. The very first notice extant about ice caves, in the shape of a letter dated 1586, of Bénigne Poissenot, a Paris lawyer, about Chaux-les-Passavant, speaks of the deliciousness of the ice water.

Draughts.—The formation of subterranean ice is sometimes—in my opinion incorrectly—assigned to air currents or draughts. Cold caves fall into two divisions in regard to the movements of air—caves with and caves without draughts. The first are ice caves proper; the second windholes or cold-current caves. Professor Thury seems to have been the first to call attention to this fact, and he divided caves into static and dynamic caves. The wind-current caves have complicated the understanding of the whole problem, as some observers have assumed that the draughts were the cause of the ice. I think the facts all tend to disprove any such idea, as very few of the observed wind-holes contain any ice. In fact, it seems as if draughts tend entirely to melt, not to form, ice. The air in an ice cave is gener-

ally almost still. I do not remember ever feeling any movement of air in an ice cave proper. In the double cave of Chapuis one cavern is filled with ice and the air is quiet, while the other is filled by a little lake, over which there is a draught. The lake is, doubtless, the result of the draught, which probably melts the ice in summer, if, indeed, it does not prevent any from forming in winter. At the entrances of ice caves I have several times noticed faint movements of the cold air outwards, but this is never perceptible within the body of caves. One cannot exactly feel the air moving out, but by lighting a cigar the smoke may be seen slowly moving outwards. At the entrance of the Kolowratshöhle there was a faint outward current when I was there. The day was a hot one and quite windless, and as the cold cave air met the hot outside air it formed a faint cloud or mist just at the mouth of the cavern.

Evaporation and Atmosphere.—Closely connected with draughts are the evaporation or expansion of the air in caves, and by some persons these are assumed as the cause of the ice. From what I have observed myself, I should say that the dryness or moisture of the air is coincident with the state of freezing or thawing of the cave. If you penetrate into a large cave about the beginning of June, when everything is frozen up tight, you will find no drips nor mushy ice; the air will be relatively dry, and the sensation of cold not unpleasant. If you penetrate into that same cave about the end of August you will find drips coming from the roof, the ice soft, and the sensation of the air a penetrating, damp cold. Thury says that in the caves near Geneva he found in summer the air so saturated with moisture that it could scarcely take up any more. In his observations with a psychrometer in the Grand Cave de Montarquis in August, he found $\frac{92}{100}$ of relative moisture. Although from what I at present know, I am inclined to disbelieve in draughts, evaporation, or expansion causing ice to form, yet I think there is need for a great deal more observation on this point.

Capillary Theory.—Another theory which has found some acceptance is the so-called capillary theory; namely, that

bubbles of air, drawn into water, flowing down through fissures in the rock, are liable to a continually increasing pressure, compelling it to part with latent caloric, which is immediately absorbed from the water on being liberated in any cave or well or mine. There may be truth in this, and I have been assured that in some borings in Western mines ice has been formed by pressure; but if it applied to caves, I do not see why so many thousands of caves contain no ice, and especially why ice caves are never known in hot countries. If the theory were correct, we should, for instance, find ice in the caves of Yucatan, described by Mr. Mercer. Still, this theory is held by some scientific observers. The Hungarian doctor at Dobsina told me he believed in it, and Dr. Schwalbe, whose opinion is entitled to great respect on account of his many observations, thinks that the rocks in summer are a cooling factor, and, that some cold comes out from them.*

Summer Ice Formation Theory.—The theories just mentioned are advanced by well-educated persons, not necessarily scientists. The natives and peasants in the neighborhood of ice caves generally believe that the ice of caves is formed in summer and melts in winter. This belief I have met with everywhere—in the Eifel, Jura, Swiss Alps, Tyrolese Alps and Carpathians. Peasants and guides will tell you with absolute confidence: "The hotter the summer, the more ice there is." The hotel keeper at Eisenerz, near the Frauenmauer Cave, told me "many people had broken their heads" in trying to account for that cave freezing harder in August than in May. This belief is founded principally on the fact that the natives scarcely ever go to an ice cave except when some tourist takes them with him, and therefore they rarely see one in winter, and their opinion is, consequently, of no value. Thury tells a good story about this belief of the peasants. He visited the Grand Cave de Montarquis in midwinter. All the peasants told him there

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*The capillary theory was first advanced by Mr. N. M. Lowe, of Boston, and published in the *Science Observer* for April, 1879. An admirable exposition of the theory by Mr. John Ritchie, Jr., was also published in the same number of the paper.

would be no use going, as there would be no ice in the cave. He tried to find even one peasant who had been to the cave in winter, but could not. He then visited it himself, and found it full of hard ice. On his return he told the peasants of his discovery. They were staggered at first. Finally one exclaimed: "It makes no difference; in genuine ice caves there is no ice in winter."

Still, there is an appearance of truth in the peasants' belief, and that is in the fact that the temperatures of ice caves, like that of other caves or that of cellars, are colder in summer than the outside air, and are warmer in winter than the outside air. Possessing neither reasoning powers nor thermometers, the peasants simply go a step further and say that the caves are cold in summer and hot in winter. In other words, from sheer ignorance, out of a true fact they make nonsense.

The extraordinary thing is that any number of writers—sometimes scientific men—in books and scientific papers, have accepted this belief of the peasants and tried to account for it. An attempt at explaining it dates back as far as 1686, in the Paris *Histoire de l'Academie Royale des Sciences.* It is found in a German book printed in 1689, then again in a French scientific journal in 1712. In the *London Philosophical Transactions,* in 1739, there is a long account in Latin about the cave of Szilize, in which the writer, a Hungarian *savant,* Mathias Bel, describes how, as soon as the warmth of spring comes, the cave begins to freeze, and, as the weather gets hotter, freezes the harder, until, in the dog days, icicles and columns grow with immense rapidity. But when the winter comes the ice all melts away, the cave becomes warm and pleasant, and the insects and the bats, and then the hares and foxes of the neighborhood come there in droves and live amicably together during the cold months. Several dozen writers in our century accept and repeat these statements as the truth. Sometimes the statements are repeated with, sometimes without, the hares and foxes, the latest repetitions occurring in 1861, 1876, and 1881.

Winter's Cold.—I now turn to the explanation which seems to me the true one, both because it is the simple and

obvious one, and because all the facts, as far as I have personally observed, entirely tally with it. This is the theory that the cold air of winter is the chief factor in producing the ice, and that it is through its means that certain caves are converted into what are practically natural ice houses. That the cold of winter produces the ice is hinted at by Gollut in 1592, by De Boz in 1726. and by Cossigny in 1743; it is elaborated into something like a theory by Prévost in 1789, and independently suggested by Townson in 1793; it is mentioned by Humboldt in 1814 and Deluc in 1822. Worked at afresh and elaborated into a theory by Thury in 1861 and Browne in 1865, it has received confirmation in our own time by the work of Professor Fugger and Captain Trouillet.

All my own observations have tended more and more to make me believe that the cold of winter is the cause of the ice, and to make my thought clearer I will put it in the form of two propositions. The first is:

The ice in caves is formed entirely by the cold of winter; the heat of summer tends to melt it. Owing to the sheltered position of cave ice, however, the summer heat reaches it with more difficulty than it reaches the snow and ice in the open, and cave ice, therefore, remains sometimes long after the ice in the surrounding country has disappeared.

The second is:

Two things are necessary for the formation of ice. The first is cold, the second is water. Therefore, to form ice in a cave, the cold air of winter must have access to it, and in some way water must be supplied to it.

Altitude and Latitudes.—The most important proof, to my mind, of the truth of these propositions, is the fact that no ice cave that I have heard of, is found in any latitude or below any altitude where ice and snow does not form for part of the year in the surrounding open country. None are reported from India or Africa, or, in fact, from any low-lying places in tropical latitudes. They are found mostly in middle latitudes, and only where during part of the year, at least, there is a cold season, that is, where, for some time, the thermometer stands below freezing point. Even in the middle latitudes they are in general at fairly high altitudes.

The Schafloch is at 1,780 meters; Skerizora in Transylvania at 1,127 meters; Dobsina at 1,100 meters; the Glacière de Saint George at 1,208 meters. It is true, there is one cave in the sub-tropical latitude of Teneriffe, La Cueva de la Nieve; but that is at an altitude of 3,300 meters, and where snow falls every year in the open on the Peak. Unless some cave is hereafter discovered in a region where there is no winter, I do not see how the imperative necessity of the presence of the cold air of winter for forming the supply of ice can be controverted.

Temperatures.—That the cold air of winter is the important factor in the production of cold seems to me also proved by the thermometric observations recorded in various caves by different observers. They all tell the same tale, that the temperatures vary with those of the outside air; that they are lowest in winter and highest in summer. Here are the results of one year's observation at Dobsina in degrees centigrade:

January,	— 4·2	July,	+ 2·1
February,	— 3·4	August,	+ 3·8
March,	— 2·1	September,	+ 2·3
April,	— 1·2	October,	+ 0·2
May,	+ 0·9	November,	— 1·9
June,	+ 1·5	December,	— 3·2

Here are a year's observations at Frain:

January,	— 5	July,	+ 3 to + 5
February,	— 5 to — 2	August,	+ 5
March,	— 1 to 0	September,	+ 3 to + 6
April,	0	October,	+ 5
May,	+ 2 to + 5	November,	+ 5
June,	+ 3 to + 6	December,	0 to — 2

These figures seem to me to prove pretty conclusively that from about the first of November to the first of May we have—inside the ice caves—winter temperatures, that is, temperatures below freezing point; and from about the first of May to the first of November we have summer temperatures, that is, temperatures above freezing point.

Positions of Entrance and Body of Caves.—A great and important factor in permitting the cold air to permeate, and remain in, a cave, is the actual form and position of the cave

and of the entrance. In all known cases, as far as I can learn, the main body of an ice cave is well below the level of the entrance, and even if the ice cave is sheltered against the wind, it is not sheltered against the cold air of winter. This is heavy, and by its own weight sinks well down to the bottom, freezing up, in course of time, all the moisture that may drip from the roof or that may come into the cave in the shape of melted snow or cold winter rain. The summer air, being warm and, therefore, light, can only enter the cave much more slowly to dislodge the winter air and destroy the ice, and before it accomplishes the latter, another winter's freeze reverses once more the conditions. This applies universally to the main body of the caves.

In all but two known cases there is a steady drop from the entrance of an ice cave to the ice. These exceptions are the Posselthöhle and the Frauenmauerhöhle, in which you first ascend gradually a short distance before the drop to the main ice begins. Both these caves are at high altitudes and well sheltered. In the Frauenmauer you have to walk through a gallery for about 30 meters, ascending in that distance perhaps 3 meters, when the slope is suddenly reversed and you then have a down grade. At the highest point, last July, I found quite a large mass of ice, enough to fill, perhaps, a couple of ice carts. But as, in ascending to the cave, I had crossed the remains of two snow avalanches, it does not seem very remarkable that better sheltered subterranean ice should remain, even if higher than the entrance of the cave. I, therefore, should not feel surprised at any time to hear of an ice cave being found with the body of the cave higher than the entrance; but this would be either at a very high altitude or in a very high latitude.*

The position of the entrance is very important. In almost all cases it has a northerly exposure, and is sheltered against

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* Since this paper has gone through the press, I have heard of a cave, "Amarnath," in the Himalayas, where the floor is said to slant upwards to the back wall. Two blocks of ice, which last through the year within the cave, are worshipped by the Hindus under the names of Siva and Ganesh, probably as re-incarnations.

entering winds. If these two conditions do not exist the ice supply surely suffers. Sometimes the entrance is more or less tortuous. In some cases it is protected by a fringe of trees. Again, in one kind of ice cave there is first a great pit, at the bottom and on one side of which we find the ice cave proper. In one case at least, the Geldloch on the Ötscher, the entrance is due south, and as a consequence the ice in the front of the cave, solid about the end of June, becomes a lake about August, and then cuts off access to the rear of the cave. In the case of the Kolowratshöhle the entrance is badly sheltered against the wind, and this undoubtedly affects the supply in summer, and causes more rapid melting there than in some other cases.

Time of Formation of Ice.—As already mentioned, cold and water are the necessary requisites for the formation of ice, and the time and method of formation were approximately explained by Thury. His winter excursions caused him to accept as proved that part of the mountaineers' belief which holds that there is no ice formed in caves in winter. He says: "In winter the cold is not wanting, but if there is no spring emptying into the cave, water is absent, and then no ice is formed. It is in the spring, at the time of the first melting of the snows, that the ice must be formed. Then water at 0° C. flows on the surface, and penetrates by the fissures of the rock and by the great openings into the interior of the chilled cavern, which receives besides the freezing night air. The grotto then makes its yearly provision of ice, which could do nothing more than diminish during the entire duration of the hot season."

Dr. Terlanday recently published a paper about the Cave of Szilize, in which he asserts that ice does not form there in winter, but that the ice first forms in the winter in the upper part of rock fissures, and that in the spring, at the time of an increase of temperature, this fissure ice is brought to the melting point by the successive entering of heat into the earth, and this water then arrives at the cave, where it aids the formation of icicles. This theory about fissure ice is probably in so far correct, that the ice in the upper parts of fissures, near the surface of the ground, melts before the

ice in the lower parts of fissures. The drip would then naturally run into the cave, and as long as the temperature of the cave was below freezing point would help to form cave ice.

But this theory does not take sufficiently into account surface thaws. Thury's theory is very good and true enough in many respects, but it does not go far enough. The observations of Professor Fugger, and especially those of Captain Trouillet, make certain the fact that ice begins to form in a cave as soon as the temperature of the cave has sunk below freezing point, whenever, from any cause, water gets into the cave. This will occur whenever there is a thaw outside at any time during the course of the winter, and it is probably entirely correct to assert that ice is formed intermittently in caves all through the winter months.

In conclusion, I wish to say that I look on this paper as in the nature of a *preliminary report* only. I have collected a great deal more information about ice caves, which I hope to publish before long. The whole subject is as yet by no means exhausted, and further observations may bring forth valuable results, and I wish I might now see American scientists give more attention to the ice caves of our own continent.

RECENT ADVANCES IN THE STUDY OF THE RESINS.*

By Henry Trimble.

HISTORY.

The earliest knowledge of the resins was probably derived from frankincense and myrrh; it is possible, by certain paintings on the walls of the ancient temple of Dayr el Báhri, in Upper Egypt, to recognize that they were important articles of traffic seventeen centuries before Christ; they were associated with such important commodities as

* Abstract of a lecture delivered before the Franklin Institute, December 4, 1896.

gold, ivory and silver. Amber, likewise, was held in great esteem by the ancients, and its history can be traced back to the twelfth century B. C.

The Mosaic writings of the Bible make frequent reference to *incense*, the chief ingredient of which was frankincense or olibanum. Later, a number of other resins appear in history; mastic is mentioned as existing in the fourth century B. C.; Venice turpentine also became known about that time, and a number of the other secretion appeared then or earlier. Galbanum, mastic and several other resins were mentioned three centuries B. C. Dioscorides recorded a still larger number in the first century of the Christian era.

The use of such resins as frankincense, myrrh, galbanum and mastic, in the preparation of their incense by the ancient Israelites, went far towards establishing the value of these drugs and in stimulating the trade in them. Some of these resins are used as incense at the present time.

The electrical properties of the resins early attracted the attention of the human race, and it is merely necessary to recall the fact that the word electricity took its name from amber because of that property. Amber was, and still is, consumed in large quantities by the Mohammedans in their worship.

Another resin, which is of interest on account of its antiquity, is scammony. Theophrastus, in the third century B. C., was acquainted with it, and it has been held in high esteem ever since.

Asafœtida was also in high repute by the ancients; it was used as a condiment in the tenth century, and the more fetid the drug the better it was liked.

These few illustrations may serve the purpose of establishing the antiquity of the resins, and especially the fact that they were considered of the greatest value by the people of ancient days.

DISTRIBUTION OF THE RESINS.

The resins are so widely distributed throughout the vegetable kingdom that there is, perhaps, no plant but will

yield some resinous substance, either by secretion or by extraction with alcohol. All parts of the plant, too, yield one or more of these substances, with the exception of the cambium, which appears to be free from resinous constituent. As a rule, the bark contains resin most abundantly, although in a few cases, as in certain conifers like the larch and our Southern pines, the sap wood contains more, and appears to be capable of secreting it almost indefinitely.

The conifers of the present time, as well as those of a former epoch, have been the great producers of resins. Those in tropical and semi-tropical climates have been found to yield them most abundantly. Usually resins are associated in plants with volatile oils, and such exudations are frequently known as balsams.

A number of resins occur in nature, which are the product of trees and plants not existing at the present time; for example, amber is supposed to have originated from pines of the Miocene period. Copal is also found under conditions which indicate that it is not derived from the vegetation of to-day, with the exception, of course, of certain of the cheaper varieties. Much of the true copal gives evidence of having been under water for a long period. In the study of the resins, therefore, it will be seen that we are confronted with some of the most serious problems in geology, and, as our knowledge of the chemistry of these substances becomes more exact, we may be able to assist in answering some geological questions by their aid.

THE PHYSIOLOGY OF THE RESINS.

This subject is closely allied to the occurrence of the resins. It is a subject, however, on which at present we have very little light.

Botanists have investigated it with the aid of the microscope, and have, consequently, drawn conclusions at variance with those of chemists.

A number of the former have concluded that resins result from the destruction of cell walls, and are, therefore, the decomposition product of cellulose.

Wiesner* believed that the starch of the cell contents contributed to the formation of the resins, and that this was effected by the aid of a middle group, namely, the tannins.

Chemists, on the other hand, usually maintain that the resins originate from the terpenes, or from aldehydes.

It is difficult to accept the theory of their origin from starch when we consider that very little starch exists in some of the tissues which yield resin most abundantly, as in the long-leaf pine. That tannins have a close relation to the formation of resin is generally conceded. The following argument in support of this has been advanced by E. S. Bastin:† "It is pertinent to note in this connection that all the facts observed regarding the oleoresins of the pines show that they are very closely associated with the tannins. While this of itself does not prove that the former are derived from the latter, the nature of the association is such as to strongly suggest such a conclusion. For example, a secretion reservoir begins in a cluster of a few thin-walled cells, rich in granular protoplasm, which early shows an abundance of tannin. Later on, oleoresinous matters appear, and, as these increase in quantity, the tannin and the protoplasm diminish, and, finally, the walls break down, leaving a cavity or intercellular space containing the oleoresin. In the meantime, cells immediately bounding this space are gradually undergoing similar changes, and so on, as long as the secretion reservoir continues to grow. So, if any well-developed secretion reservoir with the surrounding cells be examined, there will be found:

"(1) A central space filled with oleoresin.

"(2) An area of cells immediately surrounding this, which contain much oleoresin, and a little tannin and protoplasm.

"(3) Still farther exterior, a layer of very granular cells, rich in protoplasm and tannin, but containing very little volatile oil or resin.

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* *Sitzungsbericht, der k. Akad, zu Wien.*, Bd. 51; also "*Die Rohstoffe des Pflanzenreiches,*" p. 69.

† *Am. Jour. Pharm.*, **68**, 137.

"There is no denying the fact that, as the resin increases, the tannin diminishes, whatever the conclusion we may draw from the circumstance.

"The view that tannins are derived from starch apparently obtains no support from these observations on the pines.

"In regard to the origin of resin from volatile oil, the microscopic study of the pines, especially of Pinus palustris, seems to afford pretty clear evidence in the affirmative. Old secretion reservoirs have been observed to contain irregular solid or semi-solid masses of oleoresin, in which, apparently, the resin is the predominating element, while young reservoirs contain a more fluid oleoresin in the form of globules. Moreover, in the secretion cells immediately surrounding the reservoirs, the oleoresin is in globules and evidently very fluid. In fact, in passing from the younger to the older portions of the secretion tissue, there appears to be every gradation between a very liquid volatile oil and a semi-solid resin.

"There appears to be no question that the oleoresin is to be regarded wholly as a waste product. It clearly can play no part in the process of nutrition. Its only apparent use is that of protection against the destructive forms of animal life and against vegetable parasites. It is highly antiseptic, it protects mechanically against injurious insects, and its taste and effects are disagreeable to most of the higher animals."

That the resinous secretion may, in certain conifers, be diverted, so as to be an entirely different substance, closely resembling the sugars in physical properties, is seen in the sweet secretion of the sugar pine, Pinus Lambertiana, of California. While this substance does not belong to the carbohydrates in a strictly chemical sense, still, it is as closely allied to them as is phenol to the alcohols of the paraffin series.

Why one pine should secrete sugar and its near neighbor, botanically and geographically, should secrete resin is a question wide open for speculation, as well as for exact botanical and chemical research. In a number of cases gums of the carbohydrate series are a part of the resinous secretion whereby we get the gum resins.

GENERAL PROPERTIES OF THE RESINS.

The resins, as a class, vary too much from one another to have many properties in common. There are, however, a few characters which have already been cited in defining them, and which belong to all of them. They are all insoluble in water, mostly amorphous, rarely opaque, being either transparent or translucent. When pure, they are odorless and tasteless, but as they are associated, in a number of instances, with volatile oils and aromatic acids, they often have an aromatic odor and a bitterish taste. They are mostly easily melted at 100° to 150° C., although the harder copals melt above 200° C. They are usually soluble in alcohol and turpentine, and many of them are dissolved by benzol, petroleum ether, carbon disulphide and the fixed oils. The resins neither decompose nor volatilize, and they may remain unchanged in the earth or under water for centuries. An illustration of their keeping qualities occurred in 1885, when a lot of benzoin was offered for sale in London that had been raised from a wreck off the southwest coast of Africa, which occurred in 1691. The resin was found to be of excellent quality, yielding 92 per cent. of its weight to alcohol, and containing more than the ordinary amount of benzoic acid. Presumably, it should have lost some of the latter constituent during its 200 years' sojourn at the bottom of the ocean.

CHEMICAL COMPOSITION.

With the chemistry of the resins is closely allied their classification. Their classification must eventually be a chemical one, if they retain their identity as a class. Liebig was satisfied with a separation into hard resins and soft resins. This classification had previously been adopted by Berzelius, although the latter also spoke of a classification which distinguished those resins which exuded from trees spontaneously, and those which were extracted by alcohol.

About the same time, Unverdorben classified the resins according to their behavior towards ammonia. This investigator's classification is sometimes referred to by writers of the present day, but the only value it has now is historical.

He did establish a number of the properties possessed by the resins, especially their behavior towards alkalies and some metallic salts; also the electrical properties of a number of them. It may be remarked here, however, that in "Lavoisier's Chemistry" (1806) is a short account of the behavior of resins towards alkalies, and the statement is briefly made that "with alkalies it forms soap, and is much used in manufacture for that purpose, being a chief ingredient in yellow soap, and that to which it owes its solidity."

While the edition from which this quotation was taken was issued some time after the author's death, still the property of resin to form soap was, no doubt, known much earlier.

Hirschon,* in 1878, published a "scheme for the recognition of the more important resins, gum resins and balsams. While this is of considerable value analytically, it does not add to our knowledge of the chemical composition of these bodies.

We find in the text-books of to-day a nomenclature of the resins which stands in the way of a clear comprehension of their composition and properties. For instance, benzoin is said to consist of α, β, γ and δ resins, a conclusion of over half a century ago, based on the action of certain solvents. The analysis on which such a statement is based was published in *Liebig's Annalen* in 1840, and looks something like the following:

	Per Cent.
Benzoic acid	3·00 to 14·5
α resin	3·0 to 3·5
β resin	52·0 to 48·0
γ resin	25·0 to 28·0
δ resin	0·8 to 0·5
Foreign matter	5·2 to 5·5

Hlasiwetz,† in 1867, contributed a paper on the relations of the tannins, glucosides, phlobaphenes and resins with one another, and both he and Rochleder added considerably

* *Pharm. Zeit. für Russland*, **16**, 81, and *Am. Jour. Pharm.*, **50**, 130.

† Ueber die Beziehungen der Gerbsäuren, Glucoside, Phlobaphene und Harze. Von H. Hlasiwetz, *Sitzungsberichte der math.-naturw. Classe* **55**, (II), p. 575.

to our knowledge of the various resins, although no comprehensive system of classification was accomplished.

Flückiger also added much to the knowledge of individual resins, especially in reference to their history and sources.

This brings us down to the present time; and during the summer just passed Professor Tschirch, of Berne, Switzerland, has published a classification based on a study of individual resins, by himself and his students, which investigation has been progressing for a number of years. It is to be hoped that this work will be continued, for the results on the individual members of the class thus far investigated point in the direction of simplicity.

Copal, dammar, sandarac, dragon's blood, asafœtida, galbanum, ammoniac, sagapenum, opoponax, acaroid, benzoin, tolu, balsam peru, the fruit of liquid amber, storax, amber and gutta-percha have been investigated, and the following bodies have been found as the chief constituents:

(1) Resin esters, or their derivatives.

(2) Resin acids (resinolacids).

(3) Resenes, indifferent bodies of unknown origin.

Only very few of the resins contain members of all three groups. Much oftener they consist of only one member of the group.

The odor, when present, is due to ethereal oil or aldehyde, or, oftener, to a very small quantity of an ester of cinnamic acid, especially the phenyl-propyl ester of that acid.

I. The resin esters, or those containing aromatic acids are divided into two classes. One consists of compounds with benzoic acid, and the other with cinnamic acid.

(1) Benzoic ester is contained in balsam peru, balsam tolu, siam benzoin and dragon's blood. Ammoniac contains an ester of salicylic acid. Benzoyl acetic acid is contained in dragon's blood.

(2) Cinnamic ester is contained in balsam peru, balsam tolu, storax, sumatra benzoin, yellow acaroid.

An ester of cumaric acid is contained in yellow and red acaroid resin.

An ester of ferulic acid is contained in asafœtida.

Umbelliferic acid and its anhydride, umbelliferon, exist in combination in asafœtida, galbanum and sagapenum.

Most of the aromatic acids forming esters in resins are oxy-acids.

The only acid of the fatty series forming a resinous ester is succinic acid in amber.

The resin esters contain resin alcohols, which are either colorless and do not give the tannin reaction, or are colored and give the tannin reaction. The former are called *resinoles*, the latter *resinotannoles*.

(*a*) Resinoles.—Of these, four are known:

Succinoresinol,	$C_{12}H_{20}O$, in amber.
Storesinol,	$C_{12}H_{20}O$, or $C_{36}H_{58}O_3$, in storax.
Benzoresinol,	$C_{16}H_{25}(OH)O$, in benzoin.
Thirinol,	$C_{28}H_{47}OH$, in opoponax.

Spectrum analysis of their solutions in concentrated sulphuric acid shows storesinol and benzoresinol to be closely related. Succinoresinol and storesinol have the same percentage composition. All the members of the resinol group are related among themselves, and all belong to the aromatic series.

(*b*) Resinotannoles.—The following are known:

Siaresinotannol,	$C_{12}H_{13}O_2 \cdot OH$, in siambenzoin.
Sumaresinotannol,	$C_{48}H_{19}O_3 \cdot OH$, in sumatrabenzoin.
Peruresinotannol,	$C_{18}H_{19}O_4 \cdot OH$, in peru balsam.
Toluresinotannol,	$C_{17}H_{17}O_4 \cdot OH$, in tolu balsam.
Galbaresinotannol,	$C_{18}H_{29}O_2 \cdot OH$, in galbanum.
Ammoresinotannol,	$C_{18}H_{29}O_2 \cdot OH$, in ammoniacum.
Sagaresinotannol,	$C_{24}H_{27}O_4 \cdot OH$, in sagapenum.
Dracoresinotannol,	$C_8H_9O \cdot OH$, in dragon's blood.
Ponaxresinotannol,	$C_{34}H_{49}O_7 \cdot OH$, in opoponax.
Xanthoresinotannol,	$C_{43}H_{46}O_{10}$, in yellow acaroid.
Erythroresinotannol,	$C_{40}H_{40}O_{10}$, in red acaroid.

Six of these show a multiple of six carbon atoms.

In many other ways there is a close relationship among the various resinotannoles.

It is evident that the resinotannoles contain but one hydroxyl group in the molecule.

The ready formation of picric acid by treatment of the resinotannoles with nitric acid leads us to believe that the

hydroxyl is attached to the benzol nucleus, and not to a side chain. On fusing with alkali hydrate fatty acids are formed; in some cases, protocatechuic acid or resorcin is produced. The resinotannoles belong to the aromatic series.

II. The resin acids exist in the resins in the free state; they are, so far as investigated, oxy-acids, that is, contain hydroxyl and carboxyl. The following have been separated and investigated:

Podocarpinic acid,	$C_{17}H_{22}O_3$, in podocarpus resin.
Abietinic acid,	$C_{44}H_{64}O_5$, in colophony.
Pimaric acid,	$C_{20}H_{30}O_2$, in pine resin.
Succinoabietinic acid,	$C_{80}H_{120}O_5$, in amber.
Sandaracolic acid,	$C_{45}H_{66}O_7$, in sandarac.
Callitrolic acid,	$C_{65}H_{84}O_8$, in sandarac.
Trachylolic acid,	$C_{56}H_{88}O_8$, in copal.
Isotrachylolic acid,	$C_{56}H_{88}O_8$, in copal.
Dammarolic acid,	$C_{56}H_{80}O_8$, in dammar.
Guaiacic acid,	$C_{20}H_{26}O_4$, in guaiac.
Guaiaconic acid,	$C_{19}H_{20}O_5$, in guaiac.
Copaivic acid,	$C_{20}H_{30}O_2$, in copaiva.

Many of these resins are found to be related to one another.

III. The most difficult class of resins is, without doubt, the *resenes*. Their resistance to reagents has given them the synonym of indifferent material, and has made them difficult to classify. They are neither hydrocarbons, alcohols, esters, acids, ketones or aldehydes, but belong, so far as investigated, to the aromatic series.

The following have been examined:

α ponaxresen,	$C_{32}H_{54}O_4$, in opoponax.
β ponaxresen,	$C_{32}H_{52}O_5$, in opoponax.
α dammarresen,	$C_{33}H_{52}O_3$, in dammar.
β dammarresen,	$C_{31}H_{52}O$, in dammar.
Fluavil,	$C_{40}H_{64}O_4$, in gutta-percha.
Alban,	$C_{40}H_{64}O_2$, in gutta-percha.
α copalresen,	$C_{25}H_{38}O_4$, in copal.
Dracoalban,	$C_{20}H_{40}O_4$, in dragon's blood.
Dracoresen,	$C_{26}H_{44}O_2$, in dragon's blood.
Myroxoresen,	$C_7H_{10}O$, in myroxylon fruit.

When the formulas of these are carefully studied they are found to have some relation among themselves.

If it be asked what is the practical value of a classifica-

tion like this? the answer may be found in the present knowledge of benzoin compared with what it was a few years ago, when this resin was said to consist of benzoic acid and alpha, beta, gamma and delta resins. At the present time we know that this resin is a compound of benzoic acid with benzoresenol, and a compound of resinotannol, the latter varying somewhat in the different varieties.

Further than stating that the resinotannoles are peculiar compounds or mixtures of tannins and resins, we cannot at present go, except that they contain one hydroxyl group and appear to have a multiple of six carbon atoms. Certainly the chances of discovering the secret of the chemical constitution of these bodies by this road are very materially advanced, even if the task does appear somewhat formidable.

GRAPHICAL DETERMINATION OF THE INDEX OF THE POWER ACCORDING TO WHICH ONE QUANTITY VARIES RELATIVE TO ANOTHER.

BY PROF. W. F. DURAND.

It often happens in engineering investigations that a curve is found expressing the simultaneous relationship between two quantities; for example, an indicator diagram showing the relation in the cylinder between pressure and volume; or a diagram showing the relation between engine economy and point of cut-off or load; or between the resistance or power of a ship and her speed; or between the head of water-pressure on an orifice and the velocity or amount of efflux; or between the work required to remove a lathe chip and the depth or speed of cut, etc.

Now, with all such curves it is frequently desirable to determine the instantaneous index of the power according to which one of these quantities varies relative to the other. We may thus say that at a certain point in the stroke of a steam engine, the pressure, according to the diagram, varies inversely as the 1·1 power of the volume; that is, at that

point, the curve is similar to one passing through the same point, and having the equation $p\, v^{1\cdot 1} = \text{const.}$

Similarly it may be found that at a certain speed the resistance of a ship varies as the 2·3 power of speed, or at a certain load the total water consumption of an engine as the square of the load, and similarly for other relationships.

This form of expression is quite common, and the index serves a real purpose in indicating the relation between the ratios of increase of the two quantities, and therefore how much more or less rapidly one is increasing relative to the other.

In order to gain a more distinct idea of the mathematical nature of this index, let us take, as an illustrative example, the relation between the horse-power and the speed of a given ship, and let us fix our attention first on the horse-power required for a given speed, say ten knots. Then let a slight increment be given to the speed, such that the new value divided by the old is equal to $(1 + e)$, where e is a small fraction. As a result, the required horse-power will be increased by an increment such that the new value divided by the old will equal $(1 + f)$, where f is also a small fraction, but not the same as e. Then we may evidently put:

$$(1 + f) = (1 + e)^{m}$$

whence

$$m = \frac{log.\,(1 + f)}{log.\,(1 + e)} \tag{1}$$

This furnishes a definition of m in accordance with our natural ideas as illustrated in the opening paragraphs. It follows that if the speed is increased in the ratio $(1 + e) \div 1$ the power must, as a result; be increased in the ratio $1 + e)^{m} \div 1$; so that if $m = 3{\cdot}5$, and the speed is increased, 1 per cent., the power must be increased in the ratio $(1{\cdot}01)^{3\cdot 5} \div 1$, or sensibly 3·5 per cent.

It is readily seen that thus defined, the value of m would depend on the particular value of the increment e. In order then to have a definite mathematical basis for the definition of this index, it is taken as the limit of the value to which the above definition leads when the increment e is indefinitely decreased.

As another view of the nature of m, let us expand $(1 + e)^m$, remembering that since e is very small, all powers beyond the first are negligible in comparison with it. We have then:

$$(1 + f) = (1 + e)^m = (1 + m\,e)$$

whence

$$m = \frac{f}{e} \qquad (2)$$

That is, if the speed is increased by a very small part of itself, measured by the fraction e, then the power must be increased by a very small part of itself, measured by the fraction $m\,e$. This relation is exact when e is indefinitely small, and for most engineering purposes will be found sufficiently so when e is not greater than about 1 per cent.

We thus have two definitions of m which will lead to identical results when e is very small as defined. It may be mentioned in passing, however, that if m is constant (a case rarely met with in empirical relationships), then the value as given by (1) will be independent of the value of e. In such case the curve could be represented by an equation of the form $y = ax^m$, in which m is a constant. In general, such curves must be represented by an equation of the form $y = ax^n$ where n is variable, and not equal to m as here defined. Reference may be had elsewhere* for a more detailed examination of the relation of these two exponents.

The nature of the exponent m being now clearly before us, we will proceed to give methods for its determination.

In *Fig. 3*, let y_1 and y_2 denote the ordinates of the curve at A and B, and denote $O\,C$ and $O\,D$ by x_1 and x_2. Then assuming that m is sensibly constant between A and B we have, as an analytical value:

$$m = \frac{\log. y_2 - \log. y_1}{\log. x_2 - \log. x_1} \qquad (3)$$

Where many such exponents are to be found, this method is quite tedious, and it will be found much quicker and more satisfactory to make use of the following simple geo-

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* *Journal Am. Soc. Nav. Eng'rs*, **5**, 543.

metrical determination, to draw attention to which is the chief purpose of this article.

At the given point P draw a tangent $P R$ and note the foot of the ordinate Q. Then

$$m = \frac{O\,Q}{R\,Q} = \frac{\text{abscissa}}{\text{sub-tangent}} \tag{4}$$

The proof for these two values of m will be found in the appendix, for those who may be interested.

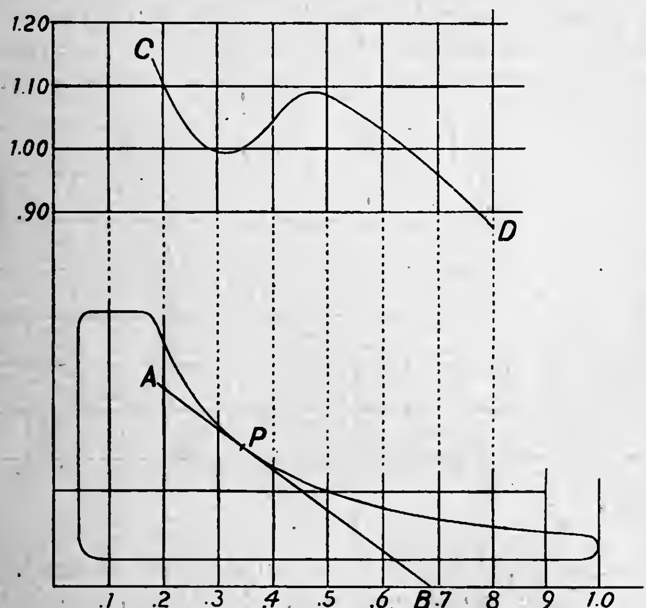

FIG. 1.

The drawing of a tangent to a given curve is subject to some geometrical uncertainty. Practically, it will be found possible to determine the direction of the line with all necessary accuracy. The tangent may be drawn simply by judgment, or somewhat more accurately by the following construction:

Assuming that the curve in the immediate neighborhood of P, *Fig. 3*, may be represented by a second degree parabola, we take two points, A and B, such that the abscissa of P is a mean between those of A and B. Or, in other words, we

take two points, C and D, at equal distances from Q, and taking the corresponding points on the curve, we have A and B. Then a line through P, parallel to the chord A B, will give the tangent desired. The proof is readily deduced from the well-known properties of second degree parabolic curves.

We will now give a few examples:

In *Fig. 1* we have an indicator card from a Corliss pumping engine, in which the equation to the expansion line is $p\,v^n = \text{const.}$, or $p = C\,v^{-n}$. The values of n for this particular card are approximately as shown by C D, the ordinates being marked in the margin. With such a curve, n

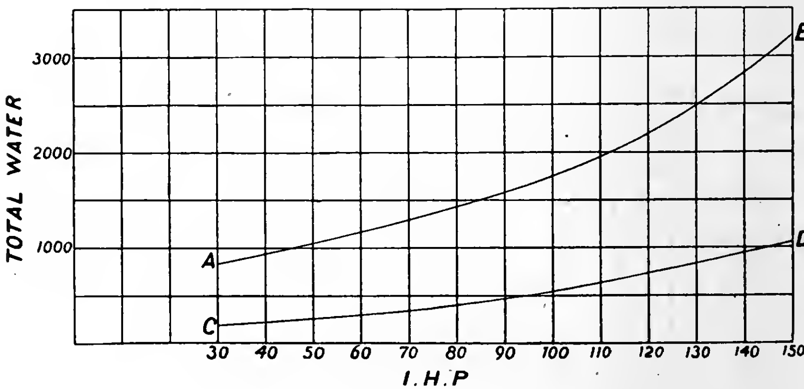

FIG. 2.

being negative, the foot of the sub-tangent B lies beyond the foot of the ordinate, instead of between the foot and the origin, as in *Fig. 3*. In any case, however, the value of m is the quotient of the abscissa divided by the subtangent.

The question of the causes of variation in the index, as shown in this diagram, is beyond the purpose of the present article, in which we are merely concerned with the determination of its value.

In *Fig. 2* let A B give the total water consumption for a certain engine developing I.H.P. as given by the abscissæ. Then, each vertical division being unity, C D shows the value of the index with which the water consumption

varies relative to the power developed. At 95 I.H.P. the total water varies directly as the power, and this is the point of minimum consumption per unit I.H.P., and, hence, the point about which there is the least variation in efficiency for slight changes in power.

At 130 I.H.P. the total water varies as the 1·7 power of the I.H.P., while at 150 I.H.P. the index has risen to 2·1, so that the variation is a little greater than as the square.

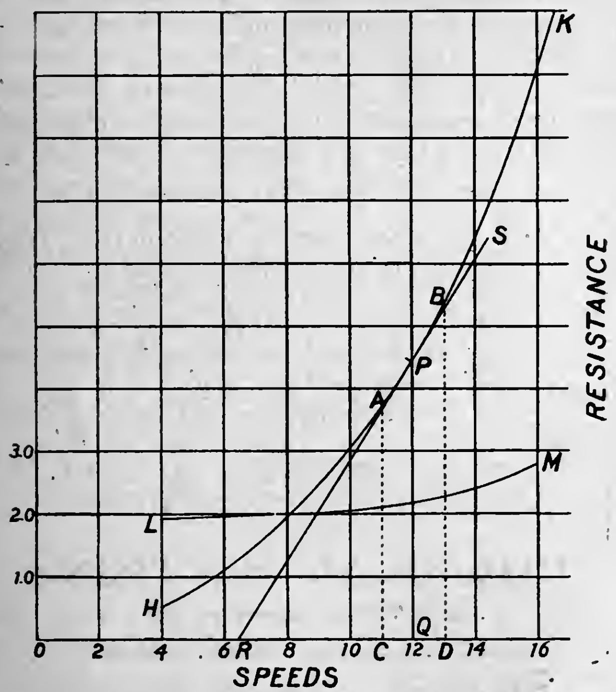

FIG. 3.

For values of I.H.P. below 95 the index decreases, showing that the rate of decrease in total water is less rapid than in power. The cause of these variations is, of course, the decreasing efficiency on either side of 95 I.H.P.

In *Fig. 3*, *H K* represents the curve of resistance of a ship at varying speeds. Then *L M* gives the variation of the index for the same conditions. At 9 *k* the resistance varies as the square of the speed, falling off slightly at lower speeds and increasing quite rapidly beyond 12 *k*.

Many other illustrations might be given, but these will serve to show the application of the method.

It will be found that the determination of this index furnishes a very delicate test of the continuity or discontinuity of algebraic law, which the curve, as drawn, represents. Many curves, which to the eye may seem smooth and continuous, will be found to have a more or less irregularly variable value of the index m. The indicator curve of *Fig. 1* shows this to some extent.

APPENDIX.

The value of m, as given in (3), is readily seen to be the value in (1) in a slightly different form ; for evidently

$$(1 + f) = y_2 \div y_1 \text{ and } (1 + e) = x_2 \div x_1.$$

For the value in (4) we take the value in (2). When the increment is indefinitely small, this is equal to

$$m = \frac{d\,y}{y} \div \frac{d\,x}{x} \text{ or } \frac{d\,y}{d\,x} \div \frac{y}{x}$$

Now, in *Fig. 3* $\qquad \frac{d\,y}{d\,x} = \frac{P\,Q}{R\,Q}$ and $\frac{y}{x} = \frac{P\,Q}{O\,Q}.$

Hence $\qquad m = \frac{O\,Q}{R\,Q}$

CHEMICAL SECTION.

Stated Meeting, January 19, 1897.

Dr. Jos. W. Richards, President, in the chair.

A NEW LABORATORY GRINDER.

Notes by Chas. A. Buck, A.C.,
Chief Chemist, Bethlehem Iron Company.

This grinder was designed by Maunsel White, mechanical engineer of the Bethlehem Iron Company, and the first one made has now been in constant use in the laboratory of that company for three years. In that time it has been worked an estimated average of five hours per day, and, so far, no part has broken, nothing worn out, nothing gotten out of repair.

It has been used there principally for iron ores (hematites and refractory magnetites), limestones, fuels, refractory materials (fire-clays, magnesite, sands, etc.).

A general average of its speed of working is that it will pulverize a charge of 30 grams of refractory magnetite from 80 mesh to an impalpable powder in fifteen minutes. By hand, this would require about one hour's steady work, and even at the best the powder would not then be so uniform. The greater fineness and uniformity of powder over the hand-ground sample facilitates solution in acids, and, in the case of fusions, often saves a re-fusion of the undecomposed residue. On an average, half an hour to an hour's time is saved in the pulverizing, and half an hour to two hours in the subsequent chemical process of solution.

The machine does the work of two strong boys in half the time, thus replacing a labor item of probably $300 to $500 a year, while the work is done so much more satisfactorily that this laboratory will, under no circumstances, ever go back to the old method of hand-grinding.

RECENT DETERMINATIONS OF THE ELECTRICAL CONDUCTIVITY OF ALUMINIUM.

By Joseph W. Richards and John A. Thomson.

Many and various values have been determined for the electrical conductivity of this metal. The causes have been as follows:

(1) The impurity of the metal used. Until 1886, the best commercial aluminium rarely surpassed 98 per cent. in purity, and it was not until 1889 that commercial metal of 99 per cent. was put on the market. As will be shown later, the effect, even within these narrow limits, is to change the conductivity nearly 10 per cent.

(2) The reference of the conductivity to copper or silver as standards. In such cases, the exact purity of the copper or silver and the physical condition of these metals, whether

hard or soft, must be known in order to give the comparison its proper value; but these were in most cases either unknown or neglected. Even at the present time, the absolute conductivity of pure soft copper or silver cannot be said to be fixed closer than within 1 per cent., so that figures for conductivity of aluminium, given only with reference to copper or silver, cannot, at best, have an accurate significance.

(3) Lack of an accurate standard of absolute resistance. The adoption of standard units of resistance, by international concert, and the consequent multiplication of registered copies, has made it an easy matter to use in experiments certified instruments of accurately-known resistance, and thus to dispense with self-constructed units of comparison in favor of more accurate standards.

(4) Imperfect methods of measurement. Of late years, several ingenious arrangements have been devised for eliminating from the calculations of experiments the resistance of connections, always an uncertain quantity, and more refined instruments for measuring and balancing electric currents have been constructed, thus permitting of increased accuracy in results.

In the following experiments, the specimens tested were kindly furnished by the Pittsburgh Reduction Company, and were all analyzed by Mr. Handy, of the Pittsburgh Testing Laboratory, so that their composition was accurately known. The conductivity is given in absolute measurement, so that no reference to any other metal as a standard can affect the results. This was rendered possible by the use of a certified standard resistance coil of 1 "International" ohm, whose possible error is not over 0·02 per cent., and by the use of the *Carey Foster* method of comparison. The metal was in wire, of 50-foot lengths, the diameter of which was measured by a micrometer and checked by weighing and determining the specific gravity. The wires were wound on wooden bobbins and immersed in oil, the temperature of which was given by a thermometer. The galvanometer used was a reflecting instrument, sufficiently delicate for all purposes. The standard coil was

immersed in water, and the room was kept at a constant temperature. The bridge wire used was carefully calibrated, and all readings were taken several times. Two separate wires were tested in case of specimen 1, the result given being the mean of two results, which differed only one-hundredth of 1 per cent. from each other.

	Analysis.						Resistance at 0° C. of a Wire, 1 Meter Long by 1 Millimeter Diameter, in Ohms.	Specific Resistance at 0° C., *i. e.*, Resistance of 1 Cubic Centimeter in Absolute (C.G.S.) Units of Resistance.	
	Aluminium.	Iron.	Copper.	Silicon.	Sodium.	Zinc.	Hard.	Hard.	Annealed.
(1) .	99·66	0·10	0·00	0·16	0·008	—	0·031245	2453·7	2432·2
(2) .	99·58	0·25	0·00	0·16	0·052	—	0·03290	2584·0	2535·0
(3) .	98·77	0·20	0·57	0·45	0·012	—	0·03627	2848·0	—
(4) .	97·16	0·25	2·26	0·30	0·032	—	0·03590	2819·6	—
(5) .	94·39	0·25	3·07	0·24	0·052	1·50	0·03583	3011·4	2984·7

For the reduction from the working temperature to 0° C. an experiment was made with wire No. (1), which showed that between 27° C. and 0° C. its temperature coefficient was 0·00392 per degree. This coefficient was used for the nearly pure wires, while for (4) and (5) a slightly lower coefficient, determined by Mr. Scott, was used. It appears that the purer the metal the greater its temperature coefficient.

Conductivity tests of a similar set of wires were made by Mr. C. F. Scott, electrician of the Westinghouse Electric Company, Pittsburgh. They were made by comparison with pure copper, with a Wheatstone bridge. These results can only be compared with ours by assuming a certain value for the conductivity of copper, and even then we cannot say how nearly the copper used by Mr. Scott would approach that standard. Sir W. Thompson's value for the specific resistance of copper is 1580, Dewar's 1562. In the following table we reduce our results to each of these standards, and add Scott's results for comparison:

RELATIVE CONDUCTIVITY (COPPER = 100).

	Richards and Thomson. Using for Copper the Resistances (1580)	(1562)	*C. F. Scott. Actual Resistance of Copper Employed not Known.*
(1) Soft	65·0	64·2	—
(1) Hard	64·4	63·7	63·1
(2) Soft	62·3	61·6	—
(2) Hard	61·1	60·5	62·2
(3) Hard	55·5	54·9	56·2
(4) Hard	56·0	55·4	58·5
(5) Soft	52·9	52·3	—
(5) Hard	52·5	51·9	55·0

TEMPERATURE COEFFICIENT FOR 1° C.

	C. F. Scott. (Between 15° and 80° C.)	*Richards and Thomson. (Between 0° and 27° C.)*
(1)	·00385	·00392
(2)	·00385	—
(3)	·00360	—
(4)	·00361	—
(5)	·00359	—

In connection with the results of Mr. Scott and ourselves, we may mention for comparison those of Charpentier-Page, who used what he calls *pure* aluminium, which may safely be assumed to be the No. 1 grade of European aluminium, averaging 99 per cent. pure. He finds as follows:

	Specific Resistance. (Calculated to 0° C.)	*Compared with Copper.* (1580) Per Cent.	(1562) Per Cent.
Soft	2659	59·4	58·8
Hard	2684	58·9	58·2

It should be noticed that these results fall exactly between our Nos. 2 and 3, also just where its composition would most probably lie. The results also agree closely with ours in showing almost exactly 1 per cent. greater conductivity for the annealed than for the hard-drawn wire.

Dewar and Fleming have also recently found as the specific resistance of "Swiss aluminium about 99 per cent. pure" the value 2563 at 0° C., which is 60·9 per cent. of that of copper, according to their own measurements. This also fits in well with our determinations, but the comparison would have been much more satisfactory if the exact composition of their metal had been determined.

C. K. McGee determined, in 1890, the conductivity of aluminium analyzing 98·52 per cent. pure to be 54·8 per cent. that of copper, when unannealed. This metal was nearly identical with our No. 3 in composition, and the results are the same within 1 per cent.

The conclusions we would draw from these experiments and comparisons are that—

The conductivity of hard-drawn commercial aluminium is strongly affected by impurities, being, approximately:

		(*Copper = 100*)
98·5	per cent. pure aluminium	55·0
99·0	" " " "	59·0
99·5	" " " "	61·0
99·75	" " " "	63·0 – 64·0
100·0	" " " " probably	66·0 – 67·0

Annealed wire has a conductivity very nearly 1 per cent. greater than the unannealed.

LEHIGH UNIVERSITY, January 19, 1897.

ELECTRICAL SECTION.

Stated Meeting, December 22, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

EQUALIZING CONNECTIONS FOR COMPOUND-WOUND DYNAMOS COUPLED IN MULTIPLE.

BY E. R. KELLER.

The successful operation of stations for electric lighting and power depends largely on the automatic regulation, not only of the speed of the prime movers, but also of the E.M.F. of the generators. In both of these essential features the last few years have brought forth marked development, in consequence of which we are now enabled to install plants for electric lighting and power, in which the speed of the engines will not vary more than 1½ per cent. from the normal, when the full load is suddenly thrown on or off, while the builders of dynamo machinery can and do supply us with generators which are almost absolutely self-regulating as to E.M.F. A modern constant potential generator will not only compensate automatically for the variable losses due to armature reaction and internal resistance, but it can be made to give an E.M.F. at the brushes which, under varying conditions of load, will be such as to compensate not only for the variable losses in the machine itself, but also those due to the resistance of the external circuit.

The success which has thus been attained in the automatic regulation of constant potential generators is largely due to the careful study and application of compound winding; and while but a few years since, nearly all of the large stations were equipped with plain shunt-wound generators, we find that these have now been superseded by the compound-wound type, in almost every class of service.

This change from shunt to compound winding has necessitated a slight modification in the connections from dynamo to switchboard, where two or more generators are coupled in parallel. For such an arrangement of generators we must employ an additional conductor between the generators, commonly called the equalizer or tie line, whose function it is primarily to prevent a possible reversal of polarity of any of the machines, and further to equalize to some extent the output of each machine under varying conditions of the external load or speed of the prime movers.

That this connection is absolutely an essential for the successful operation of compound-wound generators in multiple is beyond dispute. On the other hand, there has been a great deal of dispute in regard to what strength of current it may be called upon to transmit. In fact, its mode of action does not seem to be entirely clear to many engineers who are perfectly familiar with the installation of dynamo machinery, and who would not think of omitting the equalizer where two or more compound machines are to be used in multiple. I desire to submit a mechanical analogy, which, though deficient in many of its details, will serve to show the action of compound machines together with the equalizer connection and the function which it has to perform.

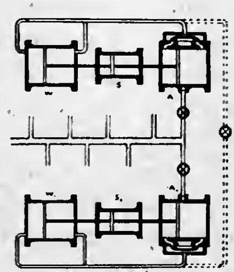

FIG. 1.

Consider, for a moment, the arrangement shown in *Fig. 1*. We have two direct-acting steam pumps located at different points along a system of distributing mains. These pumps consist of a steam cylinder *S*, a water cylinder *W* and an auxiliary cylinder *A*, through which all the water passes before it enters the supply mains. There would be no particular utility for such an auxiliary cylinder in a pump; in fact, unless the details of such an arrangement are carefully worked out, it is more than likely that such a combination would not work at all. It will suffice, however, for the sake of the analogy, and we will assume that the details are so

arranged that the mechanism will operate in the manner desired. Suppose now we have a steam pressure of 100 pounds per square inch in the steam cylinder, a pressure of 70 pounds in the cylinder *W* and 60 pounds at the beginning of the supply mains, under normal conditions. The 10 pounds difference between the 70 pounds and 60 pounds, acting on either side of the auxiliary piston, which is intended to act in a manner similar to an hydraulic engine, will help the steam piston along, and so long as the two machines continue to act under normal conditions, everything will go smoothly, each machine taking its share of the load. But now suppose that the steam pressure in one of the engines should fall to, say, 95 pounds. We would immediately have a corresponding drop of pressure in *W* to, say, 65 pounds, while in the supply mains the pressure would still remain constant. We would now have an effective pressure of only 5 pounds in the auxiliary cylinder instead of 10 pounds, and consequently a still greater reduction of pressure in *W*. This, in turn, would still further diminish the effective pressure in *A*, and so on. Presently the back pressure from the main will be greater than the forward pressure in *A*, and if the difference becomes sufficiently great, the action of the auxiliary cylinder will overpower that of the steam cylinder, and the whole mechanism will be driven backwards by the water pressure in the mains. The machine will not only cease to contribute its share of water to the supply mains, but will actually consume enough to operate it as a motor, and thus make considerably more work for the other machine.

To avoid the possibility of this reversal taking place, we connect the water pipes where they enter the auxiliary cylinders, as shown by the dotted lines. If we make this tie line sufficiently large, there will always be supplied enough pressure to the front of the auxiliary piston to prevent the pressure in the mains from reversing the mechanism, and furthermore, to equalize in a measure, the work done by each unit, under varying conditions—the equalization being the more complete, the larger the tie line.

This is precisely what takes place in compound- or series-

wound generators; and if we consider the cylinders *W* as replaced by armatures, the auxiliary cylinder by series or compound windings, the steam cylinders by the shunt windings, and the steam pressure acting on the piston by the speed of rotation of the armatures, we have two compound-wound generators coupled in parallel.

Fig. 2 shows this arrangement as commonly used. The equalizer connection, as here shown by the dotted lines, was first suggested by Gramme for series machines, and by Mordey for compound. If made sufficiently heavy, it will not only effectually prevent the reversal of polarity of any of the machines so connected, but will, in a great measure, equalize the work done by the generators under varying conditions of speed. Any number of dynamos may be connected up in this manner, and, even if they are of different

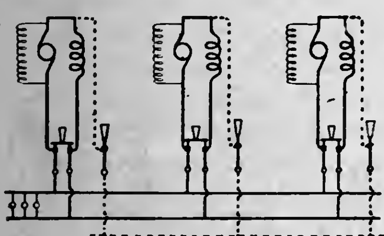

FIG. 2.

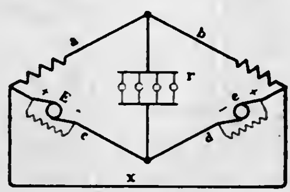

FIG. 3.

capacities, each machine will give current in proportion to its rated output, provided the combined resistances of the leads to the bus bars, the armatures and the series fields, are inversely proportional to the ampère capacities of the machines. Without the equalizer connections, or if these are not sufficiently heavy, a change of speed or of load is liable to produce a reversal of polarity in the deficient machine, in which case it will run as a motor, supplying none of its share of the current, but, on the contrary, making an additional load for the other machines, and perhaps causing a costly interruption in the operation of the plant.

The question now arises—how shall we proportion the equalizer connection?

In *Fig. 3* we have a diagrammatic representation of two compound-wound generators, of equal capacities, in paral-

lel, supplying current to a common line of resistance, r, and having an equalizer connection of resistance, x. So long as the E.M.F.'s generated by the two machines are the same, equal currents will flow through the series fields and there will be no current in the tie line. If, however, the E.M.F. (E) of one machine becomes greater than that (e) of the other, there will immediately be a greater current in the series fields of the machine generating the higher E.M.F., and a flow of current in the tie line tending to equalize the currents in the series fields, which current we will call X. But this flow of current in the equalizer will cause a fall of potential $= Xx$, and so long as there is a fall of potential in this line, the currents in the series windings, which we will call A and B, respectively, can never be equal. Hence, it

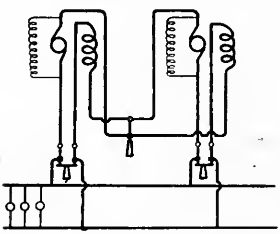

FIG. 4.

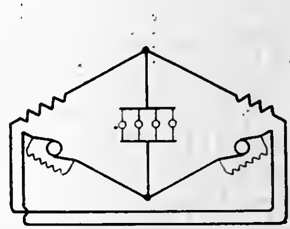

FIG. 5.

follows that we can only have A equal to B when $x = o$, which is evidently impossible.

A little consideration will further show that even if we could make $x = o$, we would not have succeeded in equalizing the currents in the armatures, but merely those in the series windings, because, if there is any inequality in the E.M.F.'s, that armature which is generating the higher will carry not only the current in its own series windings, but, in addition, that supplied to the other machine to make the two equal. That is, it will carry a current $C = A + X$, while the other armature carries only $D = B - X$. In other words, if the resistance of the equalizer could be made equal to zero, so that $A = B$, one armature would carry more current than the other by an amount equal to twice that in the equalizer.

It is evident, therefore, that in this method we effectually

prevent the reversal of polarity of any of the machines so connected, while we only tend to equalize the currents in the series windings, the tendency being the more nearly realized, the less the resistance of the tie line.

There is another method of attaining this end, and one which, if it could be successfully applied, would attain it much more perfectly. This method, which is an old one, is illustrated in *Figs. 4* and *5*.

It consists in passing the current of one armature around the series coils of the other machine, and *vice versa*. The method is perfectly feasible, and the mutual action of the output and strength of field of the two machines insures an equal division of the load.

Fig. 4 shows how this might be arranged at the switchboard, and it will be seen that by closing the single pole switch either machine could be operated alone. Unfortunately, however, this system can be used only for two machines, and moreover, these two must be exactly alike both in capacity and design. As this state of affairs rarely occurs in practice, the method has but little value.

Returning now to the consideration of the first-mentioned method, let us see what will be the distribution of the currents for given resistances, and for varying values of the E.M.F.

If, in *Fig. 3*, we let

a = resistance of positive lead and series field;
c = resistance of negative lead and parallel resistance of armature and shunt field;
} for the machine whose E.M.F. $= E$;

b = resistance of positive lead and series field;
d = resistance of negative lead and parallel resistance of armature and shunt field;
} for the machine whose E.M.F. $= e$;

r = resistance of external circuit;
x = resistance of equalizer circuit, and

A, C, B, D, R and X = respectively, the currents in the different branches of the circuit, we have, from Kirchoff's laws:

$$C = A + X \tag{1}$$
$$R = A + B \tag{2}$$
$$D = B - X \tag{3}$$
$$Cc + Xx - Dd = E - e \tag{4}$$
$$Cc + Aa + Rr = E \tag{5}$$
$$Dd + Bb + Rr = e \tag{6}$$

Solving these equations for A, B and X, we obtain, by making the necessary transformations and reductions:

$$(A + X)\,c + Xx - (B - X)\,d = E - e$$
$$(A + X)\,c + Aa + (A + B)\,r = E$$
$$(B - X)\,d + Bb + (A + B)\,r = e$$

$$Ac - Bd + X(c + d + x) = E - e$$
$$A\,(a + c + r) + Br + Xc = E$$
$$Ar + B\,(b + d + r) - Xd = e$$

$$A\,(a + c + r)\,(c + d + x) + Br\,(c + d + x) + (E - e)\,c - Ac^2 + Bcd = E\,(c + d + x)$$

$$Ar\,(c + d + x) + B\,(b + d + r)\,(c + d + x) - (E - e)\,d + Acd - Bd^2 = e\,(c + d + x)$$

$$A\,[(a + c + r)(c + d + x) - c^2] + B\,[r\,(c + d + x) + cd] = E\,(d + x) + ec$$

$$A\,[r\,(c + d + x) + cd] + B\,[(b + d + r)\,(c + d + x) - d^2] = e\,(c + x) + Ed$$

$$A = \frac{[(b + d + r)\,(c + d + x) - d^2]\,[(d + x)\,E + ec] - [r\,(c + d + x) + cd]\,[e\,(c + x) + Ed]}{[(a + c + r)\,(c + d + x) - c^2]\,[(b + d + r)\,(c + d + x) - d^2] - [r\,(c + d + x) + cd]^2} \tag{7}$$

$$B = \frac{[e\,(c + x) + Ed]\,[(a + c + r)\,(c + d + x) - c^2] - [r\,(c + d + x) + cd]\,[E\,(d + x) + ec]}{[(a + c + r)(c + d + x) - c^2]\,[(b + d + r)\,(c + d + x) - d^2] - [r\,(c + d + x) + cd]^2} \tag{8}$$

$$X = \frac{E - e - Ac + Bd}{c + d + x} \tag{9}$$

from which the currents in all the branches of the circuit may be calculated, if the resistances are known and the E.M.F.'s assumed.

It may be of interest to show, from an example, what is liable to occur in actual practice.

At one of the hotels in this city the electric lighting plant consists of two direct connected compound-wound multipolar generators, intended to give 400 ampères each at 115 volts. The internal resistances of the machines are as follows:

	Armature.	*Series Coils.*	*Shunt Coils.*
First machine	·011	·0041	15·5
Second machine	·015	·0036	11·5

The leads of the machines and the equalizers, which are arranged as in *Fig. 2*, are all about 20 feet long (to the switch-board), and they are made of a cable of 350,000 circular mills cross-section, so that

$$\begin{aligned} a &= \cdot 0047 \text{ ohms}, \\ b &= \cdot 0042 \text{ ohms}, \\ c &= \cdot 0116 \text{ ohms}, \\ d &= \cdot 0156 \text{ ohms}, \\ x &= \cdot 0012 \text{ ohms}, \\ r &= \cdot 1437 \text{ ohms (at full load)}. \end{aligned}$$

Since the machines are direct connected, there is a possibility of a variation in speed in the two dynamos, and, furthermore, there is quite a little difference in the characteristic curves of the two machines, although the field frames and armatures were intended to be exact copies of one another. Hence, a change of load may produce a material difference in the generated E.M.F.'s. Let us assume that, at full load, both machines were generating exactly 115 volts, at which voltage the current in each armature was 400 ampères, but that a change of load and speed has caused the pressure of one of the machines to fall to say 110 volts. If then we substitute the values given above for the inter-

nal resistances and for E and e, the values 115 and 110, respectively, we have from (7) and (8)

$$A = 390 \text{ ampères},$$
$$B = 374 \text{ ampères},$$

for the values of the currents in the series coils. That is, for a difference of 5 volts in the two machines, we have a difference of only 16 ampères, or about 3½ per cent. in the series field currents.

The current in the equalizer from (9) is

$$X = 222 \text{ ampères},$$

and in the armatures from (1) and (3)

$$C = 612 \text{ ampères},$$
$$D = 152 \text{ ampères}.$$

In other words, a difference of 5 volts in the E.M.F.'s of the two machines has caused a flow of current in one armature which is over four times as great as that in the other, while the equalizer has made the currents in the series windings nearly equal, there being a difference of only 3½ per cent.

Of course, these results are not accurate, because we have entirely neglected the resistances of the switches, fuses and contacts in the calculation. At the same time the results show to what extent the generators might be unbalanced under adverse conditions; and, moreover, it is evident that the equalizer may be called upon to carry currents of very considerable strength.

There are three factors which exert an unbalancing influence on a system of generators coupled in multiple:

(1) A variation of speed in one or more of the generators.

(2) A variation in the external load.

(3) A variation in the strength of the magnetizing current.

The first of these, speed variation, is, perhaps, the most serious, and we cannot attach too much importance to the matter of inherent regulation of the prime movers, the belt transmission and other factors which affect the speed of the generators.

The second, variation of the external load, affects the distribution of the load the more, the greater the divergence between the characteristic curves of the machines. As already stated, the development in this respect during the past few years has been very decided, and there is, as a rule, but little trouble from this source.

The third unbalancing factor, viz.: a change in the strength of the magnetizing current, is of a secondary nature, and would, evidently, not exist were the speed of the prime movers and the E.M.F. of the generators absolutely self-regulating. This is not the case, however, and, consequently, any variation in the distribution of the load due to the first two causes is aggravated by the third. As already stated, it is the function of the equalizer to remedy this, and it was shown that this cannot be done absolutely except by making the resistance of the equalizer = 0.

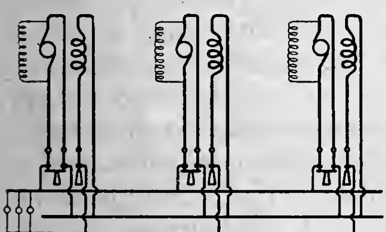

FIG. 6.

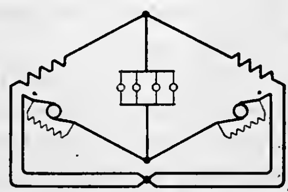

FIG. 7.

In the arrangement of Gramme and Mordey the equalizer must always have an appreciable resistance, and consequently there will always be a loss of potential in it. Moreover, this loss of potential is always at the expense of the weaker machines.

I desire, in conclusion, to suggest an equalizing arrangement in which the drop of potential in the equalizer is divided equally among the machines, in consequence of which the currents in the series windings of all the machines are equal under all conditions. The arrangement is shown in *Figs. 6* and 7.

It will be seen that this is accomplished by connecting the beginnings of all of the series coils to an extra bus bar, to which is connected also one brush of each machine, in-

stead of connecting the series windings direct to the brushes and the junctions of these to the equalizing bus bar, as in Gramme's method.

By arranging the connections in this manner it is evident that the currents in the series coils of the machines will, at all times, be proportional to the capacities of the machines, provided the resistances are proportioned in such a way that the drop of potential from the brushes of all the machines to the bus bars will be the same at full load.

Fig. 6 shows how this method would be arranged at the switchboard. The mode of operation would be as follows: Whenever it is desired to throw in an additional machine the single pole switch is first closed. This completes the series field circuit, and we immediately have a current in the series coils of the new machine, which will be proportional to its capacity. The rheostat in the shunt circuit is then adjusted until the new machine generates the desired E.M.F. After this is done the main switch may be closed without producing any further disturbance in the E.M.F. of the system.

While this system does not equalize the currents in the armatures, it does equalize those in the series coils, an effect which is only partially accomplished in the first-mentioned system. Moreover, it is applicable to any number of generators of equal or of different capacities, and in no way interferes with the continuity of operation, while the throwing in or out of additional units is greatly facilitated.

It has these disadvantages, however: It necessitates an additional conductor from the dynamo to the switchboard, and, moreover, the full current passes through the conductors which here replace the equalizer. Hence, the first cost is somewhat increased, and, further, a certain amount of energy is lost in heating the conductors. In very large installations, where the distance between dynamos and switchboard is considerable and where the currents are of great magnitude, the loss of energy which this method involves may be sufficient to preclude its application. In smaller installations, however, the increase in first cost and the loss of energy in the additional conductors will be inappreciable.

ELECTRICAL SECTION.

Stated Meeting, December 22, 1897.

MR. CLAYTON W. PIKE, President, in the chair.

X-RAYS, APPARATUS AND METHODS.

BY ELMER G. WILLYOUNG AND H. LYMAN SAYEN.

That Professor Roentgen's discovery of the X-ray has initiated many lines of thought, promising to greatly extend our knowledge of physical phenomena as well as to revise many of our previously accepted views, is generally admitted. That the practical results accruing to humanity by virtue of the applications of this discovery in surgical and medical practice, are of even greater promise and value, is equally conceded. The writers have been engaged for a number of months past in developing apparatus and methods for practical work with especial reference to the needs of the physician and surgeon. For conciseness, we have arranged the matter under consideration in a series of subordinate heads, each of which we shall briefly discuss. Your programme committee has thought that some of the results secured might be interesting, in view of the fact that very little literature regarding the technique of X-ray work has thus far been published.

The Coil or Generating Source.—Thus far the only apparatus known which will produce X-rays readily and profusely is the "transformer." By this, however, we do not mean the commercial transformer of every-day use, but its earlier, and for most purposes less efficient form, the "induction coil." Such a transformer gives exceedingly great electromotive forces capable of producing discharge over long air gaps. When the discharge from such a coil is passed through properly exhausted and constructed tubes, we have a very vigorous generation of X-rays.

Two arrangements of the induction coil are advocated. The one is known as the Tesla or "high-frequency" coil, and the other is the direct and old-fashioned use of the simple induction coil, in which the high secondary E.M.F. is delivered direct to the terminals of the tube.

The High-Frequency Coil.—Fig. 1 shows the diagram of the Tesla combination or "high-frequency" coil. It consists, as will be seen, of two induction coils, the induced secondary current of the first being used to charge a Leyden jar. The primary of the second coil is joined, in series with a spark gap, to the two coatings of the Leyden jar. When the Leyden jars are fully charged, they discharge across

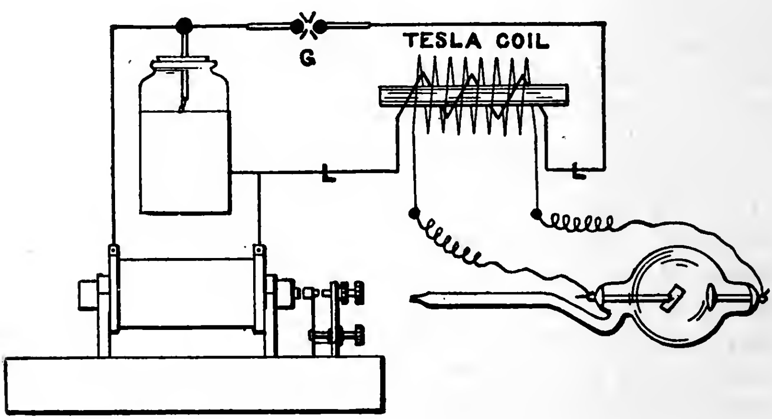

FIG. 1.

the air-gap, this discharge being, by well-known laws of electrical circuit flow, an oscillating one of exceedingly high frequency—millions or more oscillations per second. We thus have the primary of the second coil excited by an alternating current of exceedingly great voltage and frequency, so that *its* secondary produces a discharge of still *greater* E.M.F. and of this same high frequency. So great is this final E.M.F., that it is generally necessary to immerse the entire second coil, primary and all, in a tank of oil, since no solid insulation has yet been found capable of standing these great E.M.F.'s without breakdown.

To excite the Tesla coil, we may use either an interrupted direct current or an ordinary alternating circuit joined directly to the primary of the first coil. But the final result is, in either case, an alternating, high-potential, high-frequency current. In the tube, therefore, we also have an alternating discharge.

The Induction Coil.—We illustrate, in *Fig. 2*, the scheme of connections, etc., of the simple induction coil. The primary must be excited by an interrupted direct current, which may be secured from primary batteries, storage batteries, or a commercial circuit as may be determined by convenience or inclination. The secondary is joined directly to the tube

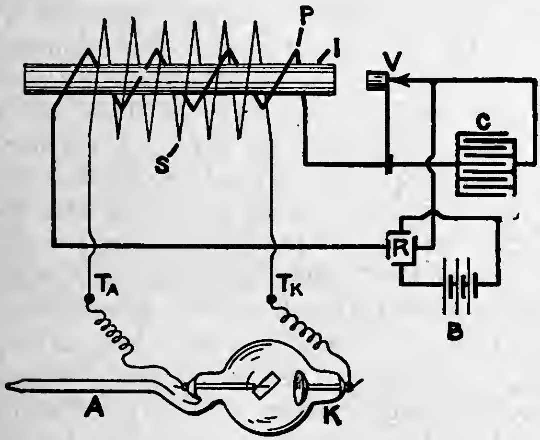

FIG. 2.

terminals. The usual means employed for securing the interruptions is some form of vibrating spring device, automatically operated by the core of the coil itself, the magnetic pull of the core attracting a mass of iron which, by its motion, separates two contact points, thus allowing a properly placed spring to draw it back, closing the circuit again, when the cycle is repeated. Such a device is employed in most forms of virbating electric bells and is indicated in the diagram. Around the break is placed a condenser. At break, this condenser charges (thus preventing the extra induced current due to the large self-induction of

the primary), but, being "short-circuited" by the primary, at once discharges about the iron core in a direction *opposite* to the regular "make" current, thus reducing (if correctly proportioned) the magnetic intensity of the iron core to zero. All this takes place so quickly that the practical effect of the action is merely to assist and intensify the dropping off of the core's magnetism—to shove it along—hasten it. Considering the secondary, now, we find that we shall have at *break* an induced discharge of greatly higher E.M.F. than that at *make*, owing to the falling off of the core's magnetism *at* break being greatly sharper than its growth at make. The effect of this is to give secondary discharges in *one direction only* at all times when the spark gap is not *greatly* shorter than the *maximum* obtainable spark gap for that particular condition of running the coil, the *make* induced current at such times being of too small E.M.F. to get across the gap at all. This is always the condition when X-ray tubes are used. A further function of the condenser is to suppress *burning* at the "break" terminals or points of interruption by taking up the energy of the magnetic discharge of the coil.

In the construction of the induction coil, a number of points may be noted. Our secondaries are wound in sections $\frac{1}{8}$-inch thick (according to the plan originally proposed, we believe, by Ritchie). These sections are separated from one another by a large number of discs of paper of a brand especially selected as free from carbon particles, and baked at a temperature a little below charring point for some time immediately before use—this to drive out moisture. These sections are then assembled and immediately immersed in a special insulation composition having a very high melting point, with high specific heat, and some slight viscosity at all temperatures.

Paraffine we absolutely prohibit as being apt to crack and absorb moisture. The melting point of paraffine, also, is so low (not over about 140° F. for the highest), that in warm weather there is serious risk of displacement of some of the sections by their own weight; for the same reason but little energy can be dissipated from the secondary.

Another grave danger in the use of paraffine is that due to the acid which it usually contains. This attacks the wire, forming copper sulphate, which dissolves gradually into and throughout the mass of the paraffine, thus effectually destroying its insulating properties.

After cooking for some time in the insulation, to drive out the last traces of moisture, the stack of sections is subjected to a further treatment, by which it is finally cooled *with all air removed.* This we consider a point of the highest importance, as air present anywhere in the secondary becomes electrified and bombards to and fro, gradually softening the insulation and eventually breaking down the coil. (For confirmation of this point, see Tesla, on "High-Frequency Phenomena.") With this plan of construction we have no static leaks of energy, or small direct leaks within the coil itself, and deliver the full energy of discharge at the secondary terminals. We find ourselves able to secure in this way a full inch of spark in all sizes of coils with considerably less than 1 pound of wire, No. 34 B. & S.* We believe that, more than anything else, the large quantities of wire required to produce a given spark length with many of the coils now in use is due to the presence of air, and consequent loss of energy by static bombardment, in the secondary. As regards the insulating composition used by us, we may say that we find its power of resistance to spark discharge to be four or five times that of hard rubber. In the arrangement of our secondary, we separate it from the primary by a heavy hard-rubber tube, and, in addition, by a tube of this composition.

The Adjustable Condenser.—A coil is working to best advantage when there is a certain definite relation between its primary current, secondary spark distance, and condenser capacity. Frequency of break must also be considered. As coils have heretofore been built, however, the condenser value has been fixed once for all and admits of no change, albeit both spark gap and primary current may be so

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* In our latest coils not over three-quarters of a pound to the inch of spark is used.

changed. To remedy this, we have devised a form of switch shown in the diagram, *Fig. 3*, by means of which the condenser capacity may be shifted, at will and instantly, by simply turning the switch. The effect upon the secondary discharge is very marked, both volume and musical note of the spark changing with the position of the switch. We find this idea exceedingly convenient in general experimental work with alternating currents, it being possible with it to alter condenser capacity as quickly and as readily as we may self-induction or resistance. (We have made some experiments in the use of a condenser in parallel *with the primary.* The volume of the secondary discharge seems, in many cases, to be greatly increased.)

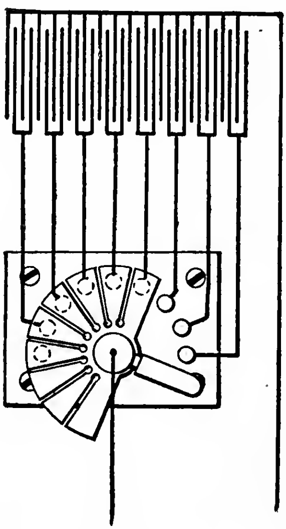

FIG. 3.

In arranging coils to operate from few or many cells of battery it is, of course, merely a matter of winding the primary with coarse or fine wire, the number of ampère turns being kept the same. It is interesting to note, as we have noted experimentally many times, that the larger the primary E.M.F. the smaller must be the condenser capacity employed, and *vice versa*. This is, of course, only to be expected, since capacity and self-induction are inverse functions of each other.

Primary Current.—This may be either from primary batteries, storage batteries, or from a commercial direct-current circuit. Primary batteries have too high resistance to give sufficient current for coils of much size—say 4 inches and over—unless joined in parallel, and then we need a number of such groups to secure the requisite E.M.F. They require constant attention, soon run down, and are expensive to operate. Storage batteries are exceedingly satisfactory, are comparatively inexpensive to operate, and require practically no attention. Charging them is more or less of an annoyance, however, especially where they must be sent

out of the building, as they usually must, besides throwing the entire apparatus out of use while the charging is going on, unless one have a reserve set of batteries.

The utilization of a direct commercial circuit, such as the Edison 110-volt (*e. g.*, where such is available), is, in every way, the most convenient and satisfactory. Until Professor Roentgen's discovery, no method of operating large coils upon such a circuit had been developed. Recently, however, several methods have been brought out, notably that of the

FIG. 4.

" air break," with air blast to blow out the spark, as used by Dr. Wm. J. Morton, Dr. M. I. Pupin, and others. In *Fig. 4* we show a form of apparatus devised by us to accomplish this purpose. A Lundell $\frac{1}{12}$ horse-power motor is supported upon a base with its shaft vertical. A casting, attached to the motor, supports above the latter a copper can made up of two concentric cylinders joined by a ring below, so that the shaft passes up through the inner cylinder and thus avoids the necessity of a stuffing-box. From the shaft is

hung, well within the can, a heavy brass wheel, having stretches of insulating slate let into its periphery. A hard-rubber lid fits over the top of the can. Mounted upon this lid are two brushes, one bearing against the wheel periphery and one against the shaft; suitable springs and screws allow the brush tension to be varied. From the commercial circuit leads are brought to these two brushes, the current being first passed through the primary of the coil and a rheostat in series. Before the lid is put in place the can is filled with distilled water; ordinary hydrant water will answer, although its usual impurity soon causes the water to become dirty, besides allowing a certain amount of electrolysis during use. With distilled water the break may be run for a number of hours without change of the water and very little heating takes place. The real function of the water is not so much to drown the spark as to prevent heating, although it does, of course, also assist in quenching the spark. But a condenser is the real spark extinguisher, and this we connect around the break just as we would around an ordinary vibrating break.

The advantages of this break over all forms of vibrating break thus far known, and over other forms of rotary break, are:

(*a*) *Convenience.*—Mere throwing of a switch being all that is required to start and stop the apparatus.

(*b*) *Noiselessness.*—Only the drowsy hum of the motor being heard.

(*c*) *Reliability.*—No chance of sticking, as with vibrating breaks.

(*d*) *Variable Rate of Break.*—Secured by adjusting rheostat in base of motor.*

(*e*) *Smooth, Unvarying Fluoroscopic Images* by reason of the large number of breaks per unit of time.

Another great advantage of the rotary break is the almost perfect control which it gives over the spark length.

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* We have found that the vacuum of a tube often gets into such a condition as to make the tube absolutely unworkable at a given frequency of break, whereas, a slight *change* of frequency immediately restores the X-radiation.

This is on account of the independence of the coil and the break, thus permitting the breaking of any desired value of current without the slightest change in either frequency or character of break. With the usual vibrating break, operated by the core of the coil, the character and frequency of break is necessarily a function of the value of current, being broken and changed with it. It is impossible, with a large coil, *e. g.*, to get uniform and continuous secondary discharges of a length very small compared with the maximum capacity of the coil, since to such short sparks would correspond a magnetization of the core insufficient to operate the vibrator at all. But with the rotary break we may make the current as small as we please, without in the slightest degree interfering with the frequency and precision of the break.

Two milled heads at top of can permit its lid (carrying brushes) to be withdrawn. A similar head at top of shaft loosens break-wheel, and two heads at bottom of can allow it to be lifted away for cleaning and renewal and replenishing of water.

We use three makes and three breaks per revolution and find best results at from 1,200 to 1,400 revolutions per minute (equal to 3,600 to 4,800 interruptions). We may secure as many as 2,000 revolutions (6,000 interruptions) per minute, by cutting out the motor regulator.

In operation, the brush bearing upon break-wheel should be *positive*, so as to prevent any electrolysis of the break-wheel. We have often broken between 15 and 20 ampères through this wheel for a considerable length of time without any overheating or excessive wear of the wheel. Should the wheel wear in time to an undesirable degree it may be removed and turned down. Provision is also made for replacing the brushes when desired.

General Considerations Regarding Break Frequency.—The question as to whether there is a certain best frequency of break for a given coil or tube or both, has puzzled not a few. Very little has been experimentally determined regarding this point. It is certain, however, that, with a given coil or tube, shortness of exposure is *not* exactly inversely as the

number of breaks. Indeed, it is often far from being so. Some of the best X-ray pictures that have been taken have been by the use of the old "hammer" break of Ritchie, and 4 or 5 clicks of the break have sufficed. Using the same tube and coil, but a rapidly vibrating or rotary break, required 40 or 50 breaks to accomplish the same results. It would appear, hence, that the energy of X-ray radiation *per break* is a function of the number of breaks per unit of time.

We are inclined to believe that this is a matter purely of the "time constant" of the coil. The iron of the core requires a certain time to magnetize and demagnetize. With the breaks few, ample time is given for this process, but when the breaks become rapid this is no longer possible, so that the secondary E.M.F. falls—this may easily be verified by observing the maximum spark length of any coil—with single breaks, few and far between, we get much longer spark maxima than if the breaks are frequent. The thickness of the sparks is also greatly increased. If, however, we increase the *primary* E.M.F. for the more rapid break we may bring up the secondary spark length to the value given by the single breaks. We should thus be able to shorten the exposure as much as we please, by merely increasing the rate of break and the primary E.M.F. at the same time; but here we are limited by the *tube* which cannot *dissipate* more than a certain definite amount of energy in a given time and will break down if overdriven. We see, therefore, that whether we use slow breaks or fast breaks, the actual time of exposure remains practically the same, the few breaks requiring to be distributed over the same *time* as the much larger number of rapid breaks. All this, of course, applies to the photographic plate. For fluoroscopy we require rapid breaks in order to escape the otherwise distressing flickering.

In the above connection, particular attention is directed to one point—the rate of break *must not be too great*. If it is, the iron no longer has time to magnetize and demagnetize. The result is an *alternating* secondary discharge instead of the *direct* discharge desired, and this means blackening of

the tube, *rapid fluctuations of the vacuum, and general deterioration of the tube. We doubt whether, with any coil of size suitable for X-ray work, a rate of break greater than 5,000 per minute should ever be employed.*

Tesla Coil or Induction Coil—Which?—Having carefully examined the results, apparatus and methods of others all over the country, devotees some of the "high-frequency" coil, some of the induction coil, and having made many and careful experiments with both forms of apparatus ourselves, we favor the induction coil. Our reasons for this preference are briefly stated:

(*a*) *Simplicity.*—One coil instead of two.

(*b*) *Ease of Manipulation.*—There being more than double the number of factors to attend to in the Tesla coil than in the induction coil.

(*c*) *Cleanliness.*—The "high-frequency" coil requires an oil bath, which must be renewed from time to time to avoid gumming. It is difficult, also, to find an oil which will not, eventually, act upon the insulation of the wire by virtue of the acid or other impurities which the former may contain.

(*d*) *Sharp Definition.*—The "high-frequency" coil produces an alternating discharge - thus with the double focus tube giving us *two* sources of X-radiation and consequent blurring of the image. If a single focus tube be used, the discharge in one direction is either lost or tears off particles of the platinum reflector, thus blackening the tube and soon destroying its effectiveness.

(*e*) *Noiselessness.*—This, from the surgeon's and physician's standpoint, is, perhaps, the most important consideraation. With tube in action, the induction coil is practically noiseless, save for the low hum of motor or vibrator. Improperly designed vibrators often rattle and rasp in a very irritating manner. In the "high-frequency" coil, however, the disruptive discharge over the air gap is the vital cause of its action. It is much more violent than a discharge of corresponding length from the induction coil, being of a rattling, cracking character. That such noise cannot but have a most unpleasant effect upon the patient who comes

into the operating room in a condition of more or less nervous collapse to begin with is obvious.

(*f*) *Strain on Tube.*—It has been argued by advocates of the "high-frequency" coil that it is much less hard upon the tubes. Our own observation has been just the reverse of this, and has satisfied us that the wear and tear is very much less with the induction coil.

(*g*) *Results.*—Although we have diligently examined, we have yet to see results obtained by any form of apparatus superior to those made in Philadelphia by Dr. Goodspeed, of the University of Pennsylvania; Dr. Stern, of the Polyclinic Hospital; ourselves, and many others who might be mentioned, and this either as regards detail, penetration or quickness of exposure. Indeed, we may say that we have never seen results obtained with the Tesla coil that are equal in any of the above respects to the results just referred to.

The Tube.—Many forms of tubes have been suggested. With practically no exception, all tubes now in use employ as cathode a concave aluminum disc, whose center of curvature is at the center of a small platinum plate ($\frac{3}{8}$ to $\frac{3}{4}$ square inch in area) the plane of the plate being inclined to the normal from center of the concave cathode. This platinum plate is sometimes made the anode—sometimes the anode is a separate plate or wire elsewhere in the tube. This form of tube is known as the "focus" tube, the cathode rays being focussed upon the platinum plate, which then becomes the active source of X-rays. In the double-focus tube we have two concave cathodes at opposite ends of the tube, the platinum wire reflector being in the form of a wedge with a side presented to each of the concave cathodes.

In the use of the tube everything depends upon the vacuum, X-rays seeming to be of a heterogeneous character, just as are light rays, their quality varying with the degree of vacuum. The higher the vacuum the more penetrating power the tube has, hence it is well to select tubes and use different tubes for different purposes. A tube of extremely high exhaustion is best for working through the body, but with forearm, hands, feet, etc., such a tube has

too great penetration, the bones appearing almost equally transparent with the flesh.

The chief difficulty with most tubes is the change of vacuum which takes place in use. This is thought to be due to the occlusion of the residual gas upon the inner surface of the glass—resulting in an *increased* vacuum; advocates of the bombardment theory believe it to mean an actual driving of the gas out through the body of the tube. It may be partially restored by heating the tube by use of a spirit lamp or Bunsen flame. This must be very carefully done, however, to avoid cracking the tube. When the platinum reflector is

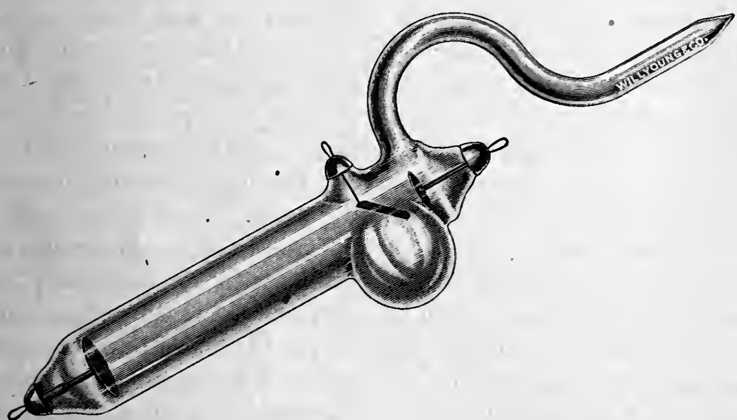

Fig. 5.

used simply as an anti-cathode, and the anode is aluminum, a simple reversal of the discharge will prove fairly successful. Some makers have adopted the scheme, practised now for many years, of blowing a small side pocket upon the tube, into which is placed phosphoric anhydride or some other chemical substance or composition absorbing moisture. When heated, this substance gives off vapor to make up for the loss; it is difficult, however, to drive off just the right amount of vapor in this way, and the vacuum is liable to be made too low, in which case flesh and bone are about equally opaque. So rapid is this change of vacuum with the majority of tubes, that in most cases involv-

ing over a few minutes' exposure or running of the tube one of the above methods becomes necessary. In any case, eventual, almost complete, exhaustion seems to be the rule, and the tube must then be returned to the makers and re-exhausted.

"Blackening" is another cause of decreased efficiency in the tube. It is due to deposition of platinum upon the inner surface of the tube.

The "Bowdoin" tube, shown in *Fig. 5*, was devised after a considerable amount of experimental work, by Profs. Robinson and Hutchins, of Bowdoin College. In general design it does not differ essentially from many other forms of focus tube upon the market. The two respects in which the tube does differ from other tubes are, first, in the arrangement of electrodes, the reflector plate not being connected to the coil at all, but merely acting as an obstacle to the bombarding rays, while the anode is a disc at the end of the tube away from the cathode. This arrangement is found to perfectly and entirely prevent blackening, no matter how long the tube may be used.

The most important feature of this tube is, however, the presence upon its interior surface of a fluorescent material which has been fused into the surface of the glass.* As the tube is used, this material, either by the bombardment or heating, or both, gives off just enough air or vapor to make up for the occlusion due to the natural working of the tube. The vacuum, therefore, tends to remain always constant. Although it seems almost absurd that one could put in just enough of this material to make up for the gas otherwise lost, yet it is a fact that these tubes remain practically unchanged in vacuum for a very long period.

In use the tube requires no "nursing" whatever. It should always have, to start with, a parallel spark gap, which should be quite small, say 1 inch or 1½ inch, and either the primary current or the vibrator tension adjusted so as to

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* The fluorescent quality is not supposed to have any effect upon the result; it merely *happens* that the particular substance found most effective is fluorescent.

produce only a very small secondary discharge. The energy of this secondary discharge may then be immediately increased until the reflector plate shows a dull red spot of about half the size of the nail of the little finger. The tube is now in its most efficient condition, and, with a well constructed and smooth working break, may be run for an hour or two without the slightest attention. The "getting ready," as above described, takes considerably less time than the time it has taken us to describe it. Indeed, in our own work, we do not trouble to make this preliminary adjustment at all, as we make it once for all when we first begin to work with a tube and do not afterward disturb it, merely closing down the switch when starting work.

Life of Tubes.—The life of tubes in general is limited—

(*a*) By time required for the vacuum to become too great, hence requiring re-exhaustion.

(*b*) By ability to stand the electrical strains.

(*a*) Applies to all tubes, so far as we know, save the Bowdoin tubes—probably six or eight hours' continuous working, or the equivalent suffices to incapacitate the average tube. We think that even with the Bowdoin tube there is an evident tendency to eventual very high vacuum, but the time required is quite large, relatively, say ten to fifteen times that operative in the case of other types of tubes.

(*b*) All well-made tubes (from the glass-blower's standpoint) are about equally liable to this limitation. It is probable that these strains are cumulative in their effects upon the tube, the latter gradually weakening until eventually breakdown takes place with secondary discharges much less than would have been originally required for breakdown.

The Stand.—The stand, shown in *Fig. 6*, has been devised by us for applied X-ray work. With it the tube may be placed in any position within a cylinder 6 feet high and 6 feet in diameter, thus making it possible to get under or over a patient, no matter what the latter's position. Four rods (two are not shown in the figure) of vulcanized fibre clamp to the stand in any position and carry the lead wires of the tube, thus keeping them away from one another and

from the metal of the stand. They carry little spring clips at their extremities, by which the wires are caught without tying or bending.* The whole stand is of bicycle tubing and very rigid.

The Subject.—The patient should, of course, be placed in as easy a position as possible. For body pictures, hip and knee joints, etc., a recumbent position may be assumed. The plate should lie beneath and upon a stiff board backing to avoid risk of breakage. Work upon the shoulder, neck, head, etc., may be done with the patient straddling a straight-backed chair, facing the back, and leaning the body against the back for support.† The plate may be bound fast to the body by bandages.

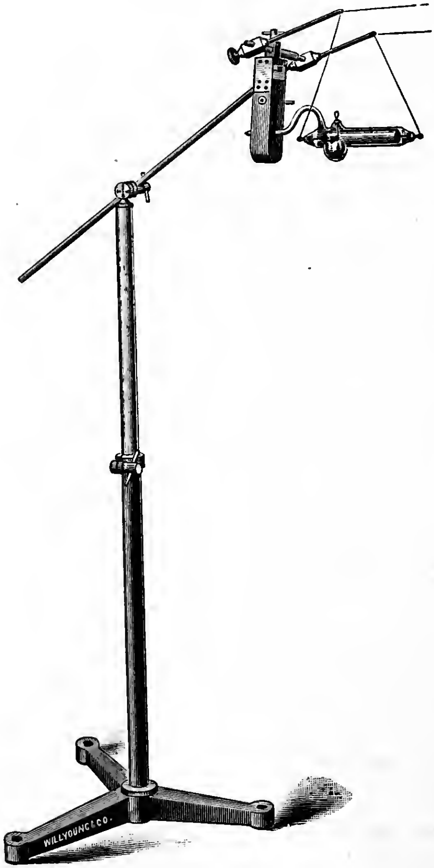

FIG. 6.

Laws for Exposure.—Since the X-rays proceed in straight lines from (approximately) a point source, the intensity of their action varies inversely as the square of the distance from the source. Hence, the *time of exposure* should vary directly as the *thickness* of the intervening substance and the square of the distance from the plate. To

* This is also a great convenience in changing the position of the stand after everything is connected up—as must often be done. The wires simply slip out of the clips, thus relieving the tube of all strain.

† For this suggestion we are indebted to the practice of Dr. Max Stern, of the Philadelphia Polyclinic.

apply these principles in practice, take a trial picture of the hand at 5 inches distance, this being amply sufficient for good definition with such small bones. Say one minute is required for a good result. Then to take a hip joint, we estimate the thickness of the latter to be, say, ten times that of the hand. We must, therefore, expose ten minutes on account of thickness alone. But, owing to the greater distance of bones from plate, the tube must be removed much further to get definition. At least 15 inches from the dry plate should be given—this is three times the distance used for the hand from which the *times* require to be as the squares of these figures, or as one is to nine. The *total* exposure must, therefore, be ninety minutes. This method gives something to go upon. After a little experience, perhaps the most convenient thing to do is to arrange a little table, based upon previous results, and showing times and distances required for well-defined results for distinctive parts of the body.

Short Exposures.—We have obtained and do regularly obtain without difficulty well-defined pictures, showing complete detail of the osseous structure involved in times and with distances from dry-plate to reflector, as below:

Hand and wrist	5 to 10 seconds,	at 5 inches.
Forearm	10 " 15 "	" 5 "
Arm above elbow	½ " 1 minute,	" 7 "
Shoulder	10 " 15 minutes,	" 10 "
Thorax	15 " 30 "	" 10 "
Hip joint	30 " 45 "	" 12 to 15 inches.
Stones in kidneys	30 " 45 "	" 12 " 15 "
Glass, iron, lead, etc., in any part of trunk	30 minutes on an average,	at 12 to 15 inches.

We have very carefully investigated every claim to quicker exposures than these, often by a personal visit, sometimes by correspondence with personal friends whose reliability was undoubted. We have been unable to learn of any results equally good having been obtained in shorter times by any one at any place with any form of apparatus, and we do not believe any such have been obtained.

Manipulation—Development of the Plate.—Suitable and well-constructed apparatus is not the only essential to good results. A great deal depends upon the operator, and com-

paratively trivial differences in procedure make all the difference between success and failure. We describe here the method which we follow and which allows us to count with certainty upon securing at least nine successful plates for every ten exposures.

General Adjustment.—First see that the coil is working smoothly and so as to give a uniform discharge in the primary. The secondary spark points should be separated by the distance given by the makers as proper for the tube. The coil must then be adjusted either by changing the E.M.F. at the primary or by variation of the vibrator adjusting springs, so as just *not* to spark over this air gap. The tube should then be joined in parallel with this secondary spark gap. The coil may then be started up, using the fluoroscope to show whether direction of discharge is right. If not, the primary current should be reversed. If X-rays are not now profuse, the secondary discharge points should be further separated and the vibrator springs tightened so as to produce correspondingly greater discharge. Continue this until either X-rays are secured as desired, or the tube becomes too hot, or possibly bluish or pink in color. Blue denotes too low a vacuum to expect X-rays, but often a gentle running of the tube for ten or fifteen minutes, while in this condition, will raise the vacuum to a suitable value. Pink denotes a *very* low vacuum and usually means, in a tube which has ever *been* right, a puncture or leak; *such a tube* can only be made good by re-exhaustion and repair. With many tubes a vivid green fluorescence is the sign of the X-ray vacuum. With the Bowdoin tubes, as also with many others, the most efficient condition is with the platinum reflector plate at cherry-red heat over an area of one-half or two-thirds that of the little finger nail.

Sometimes the vacuum will be too high for the production of X-rays with *any* length of secondary discharge. It may be reduced by gentle warming of the tube by a spirit-lamp flame. Sometimes reversal of the current in the tube will answer, but this is apt to blacken.

Sticking of the Vibrator must be guarded against—*it is often fatal to the tube.* This is because of the much larger

current through the primary when such sticking occurs. Upon release, therefore, a secondary discharge much above normal is produced, and this the parallel spark gap is unable to carry off. The tube, therefore, receives much more energy than it should, and may break down even though the parallel spark gap be as advised by the manufacturers.

(*b*) *The Plate and Its Development.*—We have used at one time and another a number of different makes of plates with very fair success. For some time past we have confined ourselves to the Carbutt X-ray plates, and though we are not prepared to say that they are the best plates to use, the results are so uniformly good as to make it seem advisable to us to try other plates not radically different in principle.

For developer, we use the Carbutt "J. C. tabloids"—3 J and 3 C, to 5 ounces of water—*add about 2 drachms of restrainer* (the usual 10 per cent. solution). Heating this developer to about 65° or 70° F. just before using, we also find to have beneficial results.

From 15 to 20 minutes will be required for development. The image will come up very slowly and not very sharply. Not much detail will be visible by holding up to the light. Continue development until the general main outlines have appeared and faded away to a general blackness upon the glass side. Then rinse and hypo.

The fixing generally requires from a half hour to two or three hours. This long time is probably *partly* due to the unusual thickness of the Carbutt X-ray films, but probably even more to some chemical condition set up by the unusually large quantities of restrainer used. Mr. Carbutt advises *3* J and *3* C tabloids to *6* ounces of water to *20-30 drops restrainer*. Our experience is that a plate so developed *always requires intensification*; a tedious nuisance, which can never give as good results as a normally exposed and developed plate.

Fluoroscopy.—As a really efficient aid to investigation or to surgical practice, the fluoroscope has thus far proved rather disappointing. In case of very definite fractures of arm or of leg below the knee, as also in certain cases of gunshot wound in these same parts, the fluoroscope will afford definite knowl-

edge. But in all troubles affecting the trunk, upper leg, etc., the indications are too blurred and vague to be relied upon. A good part of this indefiniteness is doubtless due to the *phosphorescent* quality of the screen, which causes images to be retained for an appreciable time after they are formed, so that unsteady holding produces superposed images, while we also have a molecular disturbance extending in every direction in the plane of the screen, producing visibility where no direct X-ray disturbance has been produced. Part of the difficulty is also probably due to the natural inefficiency of the screen, which, as employed in this country, is merely of tungstate of calcium. The platinum salts, especially the platinum barium cyanide, is much superior to the tungstate of calcium, but considerably more expensive; it is generally used abroad. The results obtained with it are much more brilliant than those gotten with the tungstate. It is probable that there are other salts or combinations of salts still more powerful than the platinum.

In using the fluoroscope the room should be made as dark as possible, as the eye thus becomes many times as sensitive. Good tubes are often condemned on account of lack of appreciation of this fact and because they do not reveal much detail when used in a lighted room. We have often seen tubes which would not reveal even the bones of the hand in a lighted room, which, after keeping the eyes in the dark for five or ten minutes, would give very clear fluoroscopic images of the ribs, spinal vertebræ, heart, etc.

It does not follow at all that tubes giving poor fluoroscopic results will also give poor photographic results, or *vice versa*, although usually there is a certain correspondence between the two ideas.

General Considerations.—Speaking mainly from the surgeon's point of view, only experience can insure good results with X-ray apparatus. No matter how simple the apparatus may be, how many safeguards be embodied in it, how explicit and full the directions, there are still a vast number of little points which no book can teach, no tongue tell, and which must be learned. To do the best work, one must be something of a physicist, a photographer, surgeon and doc-

tor, all in one. If he *is* not he must *learn* to be by occasionally injuring his apparatus, and certainly by breaking many tubes.

Particularly must the practitioner be cautioned against expecting too much. Many come to their fluoroscope or X-ray photograph for the first time, expecting to see the whole structure of the body exposed before them as if upon a painted wall chart. This is never the case. Except in the case of the hand, foot or forearm, but little could ever be made out in the fluoroscope were one unaware of what *should* be seen. The photographic plate results are usually better and more definite, but even here interpretation is often difficult.

Stated Meeting, January 26, 1897.

AN IMPROVED AUTOMATIC INTERRUPTER FOR INDUCTION COILS.

BY H. LYMAN SAYEN AND ELMER G. WILLYOUNG.

For a number of months we have been engaged in the systematic development of induction coils, with particular reference to their use in practical X-ray work. The requirements which must be met in such apparatus are vastly more severe than those which have belonged to induction coils as heretofore made. Up to the time of Prof. Roentgen's discovery, coils have been used only for occasional demonstration in academic class-rooms and occasionally for certain scientific investigations, as, for example, in spectroscopic analysis. Under these conditions a great many inconveniences could be put up with without difficulty. The strains put upon the coils lasted but for a short time, and occasional sticking of the vibrator or excessive burning of the contact points during the brief period of the coil's action were permissible. Now, when coils must be run for an hour or two continuously, and, further, must be run by a class of users whose training in physics and the use of physical apparatus is exceedingly meagre, it is obvious that all these

small details must be greatly perfected. A number of the improvements which we have made, we have presented to you in previous papers. We wish to-night to bring before you a new form of automatic interrupter which possesses, in our opinion, many advantages over other forms of interrupters, and which in some respects, we believe, is unique.

In *Fig. 1* we illustrate in diagram the well-known Apps vibrator, which is, perhaps, as largely used all over the world as any form of vibrator thus far devised, and which in its construction and operation is typical of the majority of known forms of vibrators. In action, the hammer-head

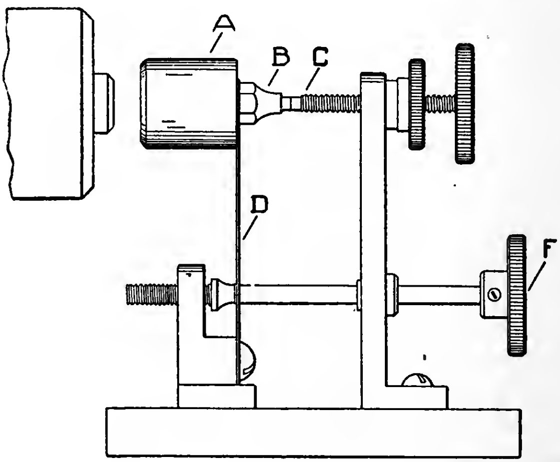

FIG. 1.

(*A*) is attracted by the iron core, thus breaking the contacts (*B* and *C*). The head (*A*) immediately flies back by virtue of the resiliency of the spring (*D*), thus again closing the contacts (*B* and *C*) and allowing the process to be repeated. The tension of the spring may be varied by means of the lower adjusting screw (*F*), which, however, it will be observed, applies the force in a manner mechanically undesirable. But the chief defect in this type of vibrator is the defective principle involved. We see that the circuit is closed by the coming together of the points (*B* and *C*). In breaking the circuit, we require, theoretically, great suddenness, but this we are obviously unable to get since the

hammer-head is at rest and requires a very appreciable time to attain any great velocity of movement, while the current is reduced nearly to its zero value by the first infinitesimal movement of the contact point, thus correspondingly reducing the magnetic pull. Furthermore, the violent blow given to the one contact point by the other throws the spring into a condition of forced vibration, which entails consequent irregular breaking and corresponding irregular discharge in the secondary.

Turning now to *Fig. 2*, we see that the plan of interrupter is entirely different from that just described. The

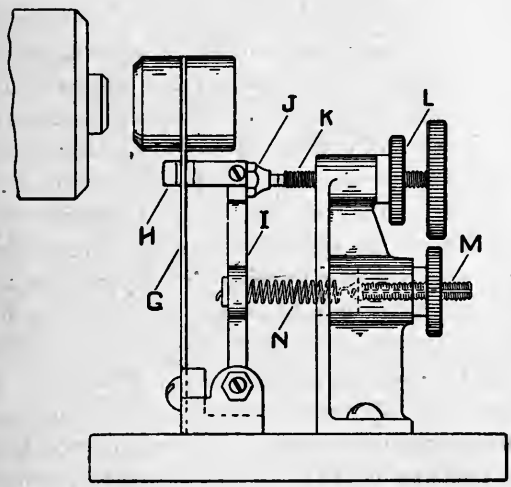

FIG. 2.

spring (*G*) is supported at its lower extremity, just as with the Apps vibrator, but is otherwise entirely free. Surrounding the spring, near the hammer-head, is a yoke (*H*), rigidly attached to a stiff casting (*I*), which is itself pivoted below. This casting carries the front contact point (J). The back contact point (*K*) is controlled by a pair of set-screws (*L*), while a lower adjusting screw (*M*) controls the tension of a helical spring (*N*), itself attached to the casting (*I*). The spring (*G*) is very stiff and when vertical stands entirely free of the yoke (*N*). In action the hammer-head is attracted by the core, but, quite otherwise than in the

Apps interrupter, is able to move a considerable distance and attain a very high velocity of motion before striking the yoke, and thus breaking the circuit. The magnetic pull on the hammer-head being thus released, the hammer-head flies back, partly by virtue of its own spring (*G*) and partly on account of the pull of the spring (*N*). The contact points coming together close the circuit once more, and the core's magnetism immediately begins again to act upon the hammer-head, the motion of which, however, it cannot instantly stop, and the head swings on, being gradually brought to rest and its motion reversed again, striking the yoke while moving at high speed.

That the suddenness of this break is vastly greater than with the Apps break is evidenced by several facts. In the first place, the arcing is practically nil, and when coils—say 8- to 12-inch even—are run with it upon a proper electromotive force, it is actually necessary often to look closely at the vibrator in order to *see* any sparking *whatever*. Further, after continuous runs for thirty or forty-five minutes, or even more, there is no appreciable rise of temperature even at the contact points, while with the Apps break the entire mass of the vibrator would have become too hot for the touch. A further evidence (and this is of decided importance) is that the same coil operated by the new vibrator, as compared with the Apps, requires not over one-half the current to produce results equally as good, if not better.*

Another feature of this new vibrator, gained for it by the characteristics which we have just brought out, is that it is capable of direct use upon a commercial circuit of 110 volts, requiring only a rheostat in series with primary to hold the current down to a suitable value. The sparking on such a circuit is greater than with battery, though not so great as with the majority of the vibrators now used with various coils when run by battery.

It is clear that with this form of vibrator we also get

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* In an actual test of a 12-inch coil, while giving 10-inch sparks, a 2-inch piece of No. 32 copper (B. & S.) wire was inserted into the primary circuit and grasped between the thumb and forefinger. The heating was not too great to be easily endurable.

rather longer makes than with the Apps vibrator. To change the speed of the vibrator we have only to screw a vertical rod into the hammer-head and upon it place an adjustable bob.

Workers with induction coils have probably noticed the irregular secondary discharge often produced where the vibrator castings were weak or insecurely fastened to the base. This is due to the parts getting in to a condition of forced and independent vibration, partly due to the shocks sustained by the contact points, and partly to the vibrations produced in the coil and reinforced by the resonance of its base. In our vibrator we have successfully overcome this difficulty by making our castings very stiff and mounting the parts upon a hard rubber base, which base we carefully surround by heavy felt, and then by a brass box, which clamps the whole firmly to the base. In this way the vibrator is not mechanically connected to the rest of the apparatus, and any vibrations transmitted to it are instantly damped out by the felt.

NOTES AND COMMENTS.*

DOMESTIC STATISTICS OF THE ALUMINUM MANUFACTURE IN 1896.

From the annual reviews of the various metal industries for 1896, published by the *Engineering and Mining Journal*, the following data relating to aluminum industry in the United States will interest many of the readers of the *Journal*:

The production of aluminum in the United States during the year 1896 was 1,300,000 pounds (650 short tons), as against 900,000 pounds (450 short tons) in 1895, showing a gain of 400,000 pounds (200 short tons), or 44 per cent. As has been the case for several years past, the entire domestic output came from a single producer, the Pittsburgh Reduction Company, whose plant at Niagara Falls has been enlarged, and has been working at nearly full capacity. The advantages of this location are very great for comparatively cheap electric power, and the company, for this and other reasons, has been in complete control of the domestic market. Bauxite is chiefly used as raw material, the company controlling the Georgia Bauxite Company, which in 1895 leased for a term of years the bauxite deposits on the Barnsley estate,

* From the Secretary's monthly reports.

in Bartow County, Ga., and began shipments in 1895. The mineral is sent to the works of the Pennsylvania Salt Company, at Natrona, Pa., where it is worked up into alumina, and the fluorides of aluminum and sodium used in the reduction process. The metal produced at the Niagara Falls plant is manufactured into sheets, bars, rods, wire, tubes, angles, channels and other structural forms, and into small articles at the Company's original works at New Kensington, Pa.

The consumption is divided on about the same lines as formerly, the larger part of the increased demand going into alloys, while the pure, or nearly pure, metal is mostly made up into such small articles as household utensils, implements, instruments, fancy goods, etc. Aluminum bronze and nickel-aluminum are in good favor. The Mitis process of making malleable iron castings with small quantities of aluminum alloy has not apparently fulfilled expectations as to the demand for the metal. For some time the French Government has been interested in the application of aluminum for military and naval purposes, as in the construction of torpedo boats, but no definite information as to results is available. Some aluminum has been used in making bicycles. While thus far the consumption has fairly kept up with the producing capacity of the American and foreign works, it does not appear probable that there is to be any great expansion of business at present prices. For scientific instruments and the usual run of small goods made of pure aluminum, the metal is perhaps cheap enough now, but this field has already been pretty well exploited. For use on a large scale, as for structural purposes in general, it has to compete with cheaper materials. Of course, there are always uses, as for warlike purposes, in which the cost might be a secondary matter in view of the specially advantageous properties of aluminum, but thus far such utilizations have been usually deferred for the future.

The following table shows the production of aluminum in the United States for six years, the figures including the aluminum used in alloys:

	Production.	
Year.	*Pounds.*	*Value.*
1891	168,075	$126,056
1892	295,000	191,750
1893	312,000	202,800
1894	817,600	490,560
1895	900,000	495,000
1896	1,300,000	520,000

From this it appears that the output has been steadily increasing, without setback in any one year, notwithstanding depression in general business; but the values have not quite kept pace with the quantities. For 1896, the average price is taken at 40 cents per pound.

The production in the United States has been somewhat over one-third that of the world. The principal European producer is the Aluminium Industrie Gesellschaft, with works at Neuhausen, Switzerland, and controlling the Société Electro-Metallurgique de France, with works at Froges, in France. In 1895 the Neuhausen works turned out about 650,000 kilograms, and the Froges works about 100,000 kilograms. The British Aluminium Company, using Irish

beauxite, has been making extensive preparations, and will now appear as a producer. The total output of aluminum in the world during 1896 has not yet been reported, but in 1895 it was approximately 1,150 metric tons (2,535,290 pounds, or 1,268 short tons).

Prices.—At the beginning of 1896 the American scale was as follows: No. 1, 98 per cent. pure, ingots for milling, 50 cents to 55 cents; No. 1, ingots for remelting, 48 cents to 53 cents; No. 2, 94 per cent. pure, ingots for remelting, 42 cents to 50 cents, the range in each case depending on quantity. These rates held until July, when we quoted No. 2, 94 per cent. pure, ingots for remelting, at 38 cents to 43 cents, and ingots from scrap at 35 cents to 40 cents; No. grade as before. In November, the Pittsburgh Reduction Company announced a reduction in prices of from 5 cents on the lower grades to 11 cents on the higher, the new schedule (which has been maintained to the close of the year) standing thus: No. 1 (guaranteed over 98 per cent. pure), ingots for remelting, 42 cents in small lots; 39 cents in 100-pound lots; 37 cents in ton lots; No. 2 (guaranteed over 90 per cent. pure, with no injurious impurities), ingots for remelting, 34 cents in small lots; 33 cents in 100-pound lots; 31 cents in ton lots; nickel-aluminum casting metal (pure aluminum alloyed with less than 10 per cent. nickel and other hardening ingredients), 40 cents in small lots; 38 cents in 100-pound lots; 35 cents in ton lots; special casting alloy (containing over 80 per cent. pure aluminum, used in place of brass), 35 cents in small lots; 30 cents in 100-pound lots; 27 cents in ton lots; castings, 45 cents per pound, upward, and special rates for bars, rods, shapes, etc.

ENGINEERING NOTES.

The *first use of Niagara's power* was made in 1725, a primitive sawmill being operated. Nothing more was done until 1842, when Augustus Porter conceived the plan of hydraulic canals, and, in 1861, one of them was completed. The Cataract Construction Company, from whose plant power has just been delivered in Buffalo, was incorporated in 1889.

CAR BUILDING IN 1896.

In its annual review of this important industry for the past year the *Railroad Gazette* reports a notable improvement over the figures of 1895, a somewhat unexpected statement.

The *Gazette* says, in the course of its comments:

"We have built, in 1896, 33,000 cars more than the total of two years ago, yet the total is still below the lowest of any year before 1894, for which we have figures that are comparable. These go back to 1888, and the lowest total in that period is in 1893, when 56,900 cars were reported built, or about 6,000 more than in 1896. But one of the large companies, whose output is included this year, did not report in 1893, so that the difference is actually larger. Comparing with 1890, the best year for car building in the last decade (the best for the locomotive builders also), we find that the 1896 output was

not half that of the earlier year, when 103,000 cars were built. In both 1891 and 1892 also the contracting shops turned out within 4,000 of 100,000 cars, so that if the records for those years represent a normal annual addition to the car equipment, the distribution of car orders, which may be looked for with a year or two of good traffic, will put great numbers of people at work. The car-building industry is a far-reaching one, and activity in it sets a long line of trades in motion."

MINERAL AND METAL PRODUCTION OF THE UNITED STATES IN 1896.

The production of minerals and metals in the United States for the year 1896 is estimated by the *Engineering and Mining Journal* at a total value of $653,311,468, showing a decrease, as compared with 1895, of $24,689,266, or about 3½ per cent. This decrease was largely in values rather than in quantities; in none of the chief articles was there any marked decrease, while in several there were considerable increases.

The total production of metals in the year 1896 was valued at $242,311,481, an increase of $1,694,111 over the previous year; while the value of non-metallic substances was $410,999,987, a decrease of $26,383,377 from 1895. A large part of this was due to the lower values of coal, stone and a few other important substances, very little resulting from the smaller quantities.

THE JACQUES CARBON GENERATOR.

Since the publication of the experiments of Dr. Jacques with an apparatus for generating energy directly from coal, the technical journals have devoted much space to the discussion of the merits of his work. The strongest adverse criticisms that have been made in relation thereto, have originated with Mr. C. J. Reed, who has challenged the correctness of the author's explanations as to the origin of the energy developed in the Jacques apparatus, and who has, we think, successfully demonstrated that the phenomena observed are thermo-electric, (deriving their source from the fuel consumed in maintaining the apparatus in action), and not electrolytic.

In a recent article published in *Harper's*, Dr. Jacques makes an interesting exposition of the subject from his standpoint. He announces certain convictions, of which we give an abstract in what follows:

The first is that the electric current was due to the chemical combination of the oxygen of the air with the coke (carbon). Quantitative tests showed that oxygen was taken from the air; that the carbon was consumed; that carbonic acid was formed. At the same time the electromotive force obtained agreed almost exactly with that theoretically obtainable from the combination of oxygen with carbon to form carbonic acid (1·04 volts). That the phenomenon was not due to the thermo-electric action was proved by the fact that when the whole apparatus was so inclosed that all parts were kept of uniform temperature the maximum electromotive force and current were obtained. Some experiments with larger apparatus have confirmed these results, and

have shown that under proper conditions the electrical energy obtainable from one of these generators is substantially equal to the potential energy of the weight of carbon consumed within the pot.

So far, only relatively small carbon electric generators have been built; and the author points out that with this generator, as with the steam engine, increased size means increased efficiency per pound of coal. Some results of a test (made by experts not connected with the development of the invention) upon a small and comparatively crude 2-horse-power carbon electric generator that has been in occasional use for some six months, are as follows: Average electrical horse-power developed, 2·16 horse-power; average electrical horse-power used by air-pump, 0·11 horse-power; average net electrical horse-power developed, 2·05 horse-power; carbon consumed in pots per electrical horse-power hour was 0·223 pound; coal consumed on grate per electrical horse-power hour was 0·336 pound; total fuel consumed per electrical horse-power hour, 0·559 pound. The electricity obtained from 1 pound of coal (of which 0·4 pound was consumed in the pots and 0·6 pound was burned on the grate), was 1,339 watt hours, or 32 per cent. of that theoretically obtainable.

These figures, it is claimed, show that the efficiency of this particular generator was twelve times greater than that of the average electric light and power plant in use in this country, and forty times greater than plants of corresponding size. There are, the author says, many details still to be worked out, and many improvements yet to be made, before the carbon electric generator can be put into general commercial use on a scale comparable with that of modern steam engines.

THE LATEST FEAT IN ARCTIC EXPLORATION.

The year of 1896 was signalized by the finding of Dr. Nansen by the Jackson party in the Arctic regions, and the announcement that on April 7, 1895, he had succeeded in penetrating northward to latitude 86·15—a point nearly 200 miles nearer the North Pole than any preceding explorer had reached. Hitherto the highest latitude attained had been 83·24, reached by Lockwood and Brainard, of the Greely expedition, in 1882. Nansen approached to about 225 miles from the pole, and he gives it as his opinion that nothing but lack of dogs and kayaks prevented him from covering the intervening distance.

His achievement opens up a new chapter in the history of Arctic exploration. Without the loss of his ship *Fram*, without any serious mishap whatsoever, even without serious discomfort, he succeeded in subtracting nearly 200 miles from the distance separating man's actual attainment from the final goal of Arctic search. It had taken about 300 years, with enormous expenditures of money, ships and human lives, and at the cost of untold suffering, for the accumulated labors of his predecessors to make an equivalent northward advance. Professor S. A. Andree's sensational attempt to reach the North Pole by means of a specially-constructed balloon closed unsuccessfully. The professor, with two companions, sailed from Gothenburg, Sweden, June 7th, on the *Virgo*, and took up quarters at Danes Island, Spitzbergen. Ad-

vices received at Hammerfest, Norway, August 6th, stated that Professor Andree had completed the inflation of his balloon and was awaiting a favorable wind. But on August 24th the *Virgo* arrived at Tromso, bringing back the expedition, which had abandoned its trip for this year owing to the lateness of the season.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 17, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 17, 1897.

JOHN BIRKINBINE, President, in the chair.

Present, 165 members and visitors.

President-elect Birkinbine, in assuming the chair, made a brief address appropriate to the occasion.

Additions to membership since last report, 26.

The Actuary transmitted from the Board of Managers a memorial of the late Chas. H. Banes. The Secretary read the memorial, which was accepted and ordered to be referred to the Committee on Publications.

(This publication will be made in the impression of the *Journal* for April, 1897.)

A communication was read from Mr. W. P. Tatham, tendering his resignation as Vice-President of the Institute. The resignation was accepted.

An election was held to fill the vacancy thus created, which resulted in the choice of Mr. Alfred C. Harrison.

A communication from Mr. Jos. M. Wilson, the retiring President, was read, conveying his acknowledgment of the resolution of the Institute, passed at the annual meeting of January 20, 1897, in reference to his retirement.

Mr. Thomas Corscaden, of the American Pulley Company, of Philadelphia, gave a description of the "All-Wrought-Steel Belt Pulley" of his invention, manufactured by the company above named. The speaker illustrated the subject by the exhibition of a specimen pulley, and of the parts of which it is composed.

Mr. John Carbutt, by special request, gave an experimental demonstration of the apparatus and operative methods employed in X-ray photography.

The Secretary read a communication from the President of the Association of American Draughtsmen, inviting the members and friends of the Institute to attend a lecture on "Aërial Navigation," by Mr. Wm. N. Howell, to be given in the Hall of the Institute, on Thursday, February 18, 1897, at 8 o'clock.

Adjourned. WM. H. WAHL, *Secretary*

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FOOD ADULTERATION AND THE PURE FOOD LAW.*

BY DR. LEE K. FRANKEL, Member of the Institute.

On the 26th day of June, 1895, a little over nineteen months ago, the Legislature of Pennsylvania passed the first general act regulating the sale of food within this Commonwealth, and providing against the adulteration of all articles of food and drink.

Judging from the comparatively short time that has elapsed since the question of food adulteration has received such general attention at the hands of our legislators, it might be supposed that the sophistication of food-stuffs is itself of very recent origin. Not only is this not the case, but the history of the subject indicates very clearly that ever since the day when barter and trade arose, ever since the time when commerce began to flourish, the instincts of

* A lecture delivered before the Franklin Institute, February 5, 1897.

gain and profit in the human breast have led men to impose upon their fellow-beings, and to offer for sale food and drink in a fraudulent and adulterated form.

It is naturally a difficult matter to state how early in the history of the world's civilization the practice of food adulteration began. Not only are the records of those early centuries incomplete and uncertain, but the intellectual and commercial development was so meager as to preclude the possibility of falsification, except within the very narrowest limits.

I believe, however, that we are safe in assuming that in ancient Egypt, even if deliberate adulteration was unknown, the distinction between pure and impure substances already existed. For example, in the Book of Exodus, under the laws which govern the construction of the tabernacle and its appurtenances, the children of Israel are explicitly commanded to bring *pure* olive oil for the lighting of the ark. If we remember Henry George's statement that the ancient Hebrew institutions show in so many points the influence of Egyptian ideas and customs, and that what is remarkable is the dissimilarity, we will not be stretching the imagination too far in assuming that olive oil in an impure and adulterated form was in use among the Egyptians.

The Bible itself contains no direct reference to food adulteration, nor are there any laws mentioned that control it. In the later rabbinical literature, however, and particularly in the Talmud, are given numbers of opinions of the rabbis as to what shall constitute a pure or an impure food. In the addidamenta to the Talmud, known as the "Tosefta," which are supposed to have been written in the first or second century before Christ, the following adulterations are mentioned: The addition of water to wine; the use of the juice of the glaucion in oil, to pass for poppy oil. The glaucion was a plant like the horned poppy, which was, in ancient times, often fraudulently substituted for poppy. There is likewise mentioned the use of the juice of the fruit of the arbutus, or wild strawberry tree, in honey; the use of flour in honey; of vinegar in oil; gum (cummis) in myrrh; sand in bean flour; asses' milk in balsam; rock-lichen or red paint

in brine; coriander in pepper. Similar adulterations are mentioned in the commentary on the Book of Leviticus, known as "Sifra Vayikra," and which is supposed to be even older than the "Tosefta." In this commentary we find some slight variations from the above, arising from corruptions of some foreign names. In the "Tosefta Babahamma" there is mentioned the adulteration of the stalks of asparagus with stalks of fenugrek; the seeds of St. John's bread with seeds of fenugrek, and the use of vinegar with oil. The same is mentioned in the "Mekhilta," the commentary on the Book of Exodus, which is as old if not older than the "Sifra."

In ancient Greece and Rome adulteration was frequently practised. Dioscorides mentions the adulteration of opium with gum and with the milky juice of the glaucium and lactuca, which is evidently a form of adulteration similar to that mentioned in the Talmud. In Athens the adulteration of wine was so frequent that it became necessary to appoint special inspectors, whose duty it was to prevent such adulteration. History has handed down to us the proverb: "Artificial as Canthare." The origin of this expression lies in the fact that a certain Greek named Canthare, understood so thoroughly the art of imparting to new wines the flavor of age that his name became proverbial.

In Rome, Pliny tells us, the frauds practised by the bakers were very extensive. The addition of a white earth, which was obtained from a hill in the neighborhood of Naples, to the bread in order to give it weight and body, was a practice commonly resorted to. Wine, too, was badly adulterated in Rome; so much so, indeed, that Pliny states it was impossible even for the rich to obtain the natural wine of Falerno in a pure form.

It is not, however, until the time of the middle ages that we find systematic records of food adulteration. From this time likewise begins the introduction of police regulations restricting the sale of adulterated and in particular of diseased food. In England, as early as the reign of King John, a regulation, called the assize of bread, provided for the sale of bread according to certain definite weight and size.

This assize was eventually extended to include meal that had become musty, and prohibited the sale of rotten and diseased meat.

Along with the bakers, the brewers, vintners and pepperers or spice dealers were the chief malefactors, and were severely punished for their crimes. As early as 1529, official ale testers were appointed, whose province it was to test the product of the brewer before the latter could sell it. Their method of testing, according to Blythe, was certainly unique, if not accurate. The ale was spilt on a wooden seat, so common in the ale houses of that period, and the tester sat on the wet place attired in leathern breeches. If sugar had been added to the ale or beer, the tester adhered so tightly to the wooden bench that rising became difficult. The ability to rise with alacrity indicated an extract that had no adhesive properties, and hence, the absence of sugar.

In France, as well as in Germany, official recognition of adulterated food is nearly synchronous with that in England, and the special fields in which restriction was imposed are about the same. The bakers, brewers and vintners seem to have been the ones who offended most flagrantly, and the punishment imposed was correspondingly severe. The ducking stool, the stocks, the pillory, the imposition of a heavy fine, and even burning and burial alive, were forms of punishment resorted to.

In the colonial laws of this country we find references to food legislation at a very early date. Before the arrival of William Penn, that section of country now known as Pennsylvania was regulated by what are known as the Duke of Yorke's laws. In these, as early as September 22, 1676, six years before Penn's arrival, we find an act which states: "That no person whatsoever shall henceforth undertake the calling or work of Brewing Beere for Sale, but only such as are known to have sufficient skill and knowledge in the art or mistery of a Brewer. That if any undertake for victualling of ships or other vessels, or master or owner of any such vessels, or any other person shall make it appear that any Beere bought of any person within this government do

prove unfit, unwholesome and useless for their supply, either through the insufficiency of the Mault, or Brewing, or unwholesome Cask, the Person wronged thereby shall be and is hereby enabled to recover equal and sufficient damage by Action against that Person that put the Beere to sale."

In these same laws of the Duke of Yorke we find a regulation requiring packers of beef to take an oath that they will pack no goods but those that are good and sound.

After the arrival of William Penn, the Assembly which met at Philadelphia in March, 1683, provided an act regulating the size and weight of bread and of butter. Later, in 1705, an act was passed regulating the sale of liquor, which stated that "if any person within this province shall presume to sell rum, brandy or such like spirits, that is adulterated or mixed, with water or any other liquor, knowing the same to be so adulterated or mixed, being convicted thereof by one or more creditable witnesses, he or she shall, for every such offence, forfeit the said rum, brandy or spirits to be exposed to sale and pay treble the value thereof, one moiety to the support of government, and the other moiety or half to him that shall discover and prosecute the same."

Later, in 1775, we find an act regulating the sale of bread and flour, and providing a fine of £5 for the sale of either containing improper or unwholesome ingredients. In 1835, under the Inspection Laws, are regulations for the sale of flour and meal, beef and pork, salted fish, butter and hog's lard. The law of 1775 was further amended in 1854, 1858 and 1860. From this period we have quite a number of special enactments referring to adulterated drugs, candy, milk, oleomargarine, butter and cheese, unwholesome meat and vinegar. Eventually we have the general law of June, 1895, mentioned at the beginning of the lecture.

With this introductory sketch we may leave the historical development of the subject, and consider the question of food adulteration as we find it to-day.

It will probably come as a surprise to many, that the tendency existing among manufacturers and dealers to-day, to produce and sell articles of food which are either below standard, or different from what they are represented to be,

is not an insignificant fact, but a condition which has developed remarkably within the past decade. If it be remembered, furthermore, that in a number of instances, the adulteration which is practised is not only fraudulent, but at the same time also a menace to the health of the consumer, it will be seen that the condition which confronts us contains the elements to create a justifiable alarm.

The cause of this remarkable state of affairs is not difficult to trace. It must be sought in the fierce competition which is so prominent to-day in all classes of trade; in the tendency of the masses to buy that which is cheap rather than that which is good; in the inability of the poor to purchase pure food at the price which is demanded for it; and lastly, in the ignorance which renders the consumer unable to discriminate between what is wholesome and what is injurious.

The extent to which food adulteration is carried in the United States is a matter of doubt. The estimates of competent authorities on the subject vary between 2 to 15 per cent. There can hardly be any question that the first figure is too low. The last is given by Mr. Wedderburn, the special agent of the Department of Agriculture, who has examined the subject very exhaustively. Good judges estimate the value of the food supply of the United States at a minimum of $4,500,000,000 annually. If we take the very conservative estimate of 2 per cent., the loss to the consumer by adulteration amounts to $90,000,000 per year. Dr. McNeal, of Ohio, estimates the annual loss to the people of the United States at 1⅓ billion dollars; and to the State of Ohio, as the result of three years' investigation, a loss of $78,000,000 annually, or $232,000 per day. It is immaterial for the purposes of this lecture, which of these figures is correct. Either amount is sufficiently large to prove that the actual money loss to the consumer arising from the purchase of food-stuffs other than they are represented to be, is so great as to merit attention at the hands of the individual, the State and the national government.

Nor does it seem that the sophistication of food is confined to any particular district. The fact that nearly every

State in the Union has either general or special laws regulating the sale of food, affords in itself sufficient evidence that these laws were enacted in answer to a crying need for them. Furthermore, the reports of the Commissioners, Boards of Health and other officers appointed to administer the laws in the various States, show that the falsification and adulteration are systematic and general throughout the country. What is true of the extent of adulteration, so far as territory is concerned, is equally true of the kinds of food adulterated. It would be difficult to find a single food-stuff requiring preparation to make it palatable, that has not been subjected to the skill of the sophisticator, or which, on investigation, will not, to a greater or less extent, disclose the hall-mark of fraud.

Several years ago the national Department of Agriculture, under the superintendence of its chief chemist, Dr. H. W. Wiley, instituted a series of investigations of the more common food-stuffs, such as molasses, sugar, honey, confectionery, canned goods, etc. Letters were addressed to prominent chemists in the States of Indiana, Nebraska, California, Kentucky, Massachusetts, Louisiana, Pennsylvania, Ohio and New York, with the request that they purchase samples of the above articles in their respective States, examine the same and report on their condition of purity. The department at Washington at the same time conducted a similar series of tests on articles of food sold in the vicinity of the capital. The results obtained from the examination of molasses and syrup are in the main a criterion of the results found with the other articles of food examined. As a rule, each chemist analyzed fifty samples, with the following results: Indiana showed 32 samples which contained tin; of the Nebraska samples, 35, or 70 per cent. contained glucose; of the California samples, 11, or 22 per cent. contained glucose; 19, or 38 per cent. of the Kentucky samples were found to contain the same ingredient. Worthy of notice is the fact that Massachusetts, the State in which the food laws have been most rigidly enforced, showed the smallest percentage of adulteration, only 8 of the samples, or 16 per cent. containing glucose; Louisiana,

the headquarters of the molasses industry, gave 16 samples adulterated, or 32 per cent.; Pennsylvania's report does not redound to her credit, as 31 samples, or 62 per cent. contained glucose; of the samples examined in Washington, of which 25 were bought in Washington and 32 in Baltimore, 14 of the Washington samples and 13 of those from Baltimore contained glucose. Furthermore, 32 of the samples contained tin and 19 copper. The samples examined in these ten sets represent the greater number of the producers to be found in the United States, and probably no better illustration could be given of the extent of food adulteration than is represented by these few figures.

The character of food adulteration goes hand-in-hand with the extent of the adulteration and the kinds of food adulterated. It is simply astounding to what extremes the rapacity and ignorance of the producer have led him in order to increase his profits. Were the adulteration entirely of such a nature that the consumer's pocket-book only was injured, it is possible that extenuating circumstances for such fraud might be found, and the offence in a measure condoned. But when substances are added to our foods which are known to have harmful effects on the human organism; when the adulteration consists of the addition of drugs and chemicals which, when taken into the system, are known to be cumulative poisons—and it has been repeatedly shown that such adulteration is practised—then we can only pray that the world at large may soon be educated up to the standard of seeing that it must, for its own protection, stamp out this evil of adulteration with every force that it can exert.

To bring this matter more clearly before you, let us leave generalities and consider in detail some of the adulterations that have been and are being practised to-day on the more common articles of food. Of these probably none are so important as the two in daily use by all classes of people of all ages, viz.:

MILK AND BUTTER.

The chief adulterant of milk, an adulterant most plentifully found, and one having the special advantage of cheap-

ness, is water. Formerly, the addition of flour and starch to milk was occasionally attempted, but it is not probable that such sophistication exists to-day in other than isolated cases. In the last few years, the tendency to add preservatives to milk has grown quite common. In fact, so prevalent has this practice become, that many State legislatures have made it a subject for legislative action, and in Pennsylvania we have a special enactment whereby it is a misdemeanor to add to milk, boracic acid salts, boracic acid, salicylic acid, salicylate of soda or any other acid, drug, compound or substance. Legislation against the addition of water is likewise general throughout the States, and special enactments, defining explicitly what shall constitute pure milk, are the rule rather than the exception. In Pennsylvania, for example, standard milk must contain 12½ per cent. of milk solids, 3 per cent. of fat, and must have a specific gravity ranging between 1·029 and 1·033 at 60° F. Under adulterated milk, there is included also milk obtained from diseased cows or from cows fed on putrid substances, the selling of such milk being made a misdemeanor and punishable.

The adulteration of butter is of so peculiar a kind and has such widespread significance, that the legislation on the subject has been undertaken not only by State legislatures, but by Congress as well. We may leave out of consideration adulteration by preservatives, such as we met under milk, since what is true of milk in this instance is likewise true of butter. Of far greater importance is the adulteration or substitution of butter, the product of milk, by the artificial product obtained from animal or vegetable fats, and known as oleomargarine, margarine, butterine, etc.

It is not within the province of this lecture to discuss, either *pro* or *con*, the question of the value of oleomargarine and similar products as food-stuffs. Much has been said and even more has been written on this topic, and I believe that I am safe in saying that to-day even experts are undecided. Whether milk fats are more digestible than animal fats, whether the germs which may remain in oleomargarine at the low temperature at which it is produced, are more

pathogenic in their nature than those which find a habitat in the cow-yard and in the stable, are not questions for us to decide. Our interest in the matter begins when there is sold, as pure butter, any oleaginous substance or any compound of the same other than that produced from unadulterated milk, or cream from the same; and here, too, our interest virtually ends. Until it is definitely proven that oleomargarine and similar products are injurious to the human organism, their sale, when sold as such, does not come under the scope of food adulteration. This fact has been taken cognizance of in our national legislation. The United States allows the sale of oleomargarine and its allies, when the seller is properly licensed and when the special laws as to branding, marking, etc., are fulfilled.

The State of Pennsylvania, however, has taken an extreme stand in the matter. By an Act of Legislature, it is a misdemeanor for any person, firm or corporate body to manufacture, sell, or offer for sale, or have in his, her or their possession, with the intent to sell the same as an article of food, any article made out of any oleaginous substance, or any compound of the same other than that produced from unadulterated milk or cream from the same, or any article designed to take the place of butter or cheese produced from pure unadulterated milk or cream from the same, or of any imitation or adulterated butter or cheese. By this law, oleomargarine and similar products, and what is known as filled cheese, viz.: cheese to which animal or vegetable fats have been added, are completely excluded from Pennsylvania.

If we examine more closely, however, we shall find that the true inwardness of this law has nothing to do with food adulteration. Below and beneath the verbiage of the enactment is the fact that the law was framed not necessarily to insure wholesome food, but to protect the large and still growing dairy industry of the State. Statistics have shown that the products of butter and cheese in the United States amounted, in 1889, to $245,000,000, or $39,000,000 more than the product of all of the gold, silver and iron mines in America. The State of Pennsylvania produces annually

100,000,000 pounds of butter, so that every individual who owns even a single cow—and of these there are many—is directly affected by the dairy question. Opposed to this is the fact that the entire oleomargarine industry is in the hands of less than twenty-five men. I believe this statement indicates with sufficient clearness that the true tenor of the law was the protection of a large number of the residents of Pennsylvania against the supposed encroachments of a few outsiders. Whether this is within the province of the State is for others to decide. It does not come within the province of this lecture.

Next in importance to the products of the dairy are those of our cereals and leguminous plants.

THE STARCHES AND VARIETIES OF FLOUR.

Fortunately for us, adulteration among these products is the exception rather than the rule, particularly in the United States. What adulteration there is consists mainly in the partial substitution of one flour or starch by another. In wheat flour, for example, in the few cases that have been reported, the adulteration consisted of damaged peas, ground rice, corn meal, and rarely the addition of alum, to increase the whiteness. Under adulteration must also be considered musty flour and flour containing dirt and smut. Buckwheat is adulterated with wheat and other flours; sago with potato starch.

With the products of flour, such as bread, buns, cake, macaroni, vermicelli, etc., the adulteration, while more frequent, is likewise not very pronounced. Bread is said to be adulterated with alum, sulphate of copper, ammonia, flours other than wheat and inferior grades of flour. It is questionable if these adulterations are practised to any extent in the United States. In England and on the Continent a number of cases are on record, in which the above adulterations were found and the offenders prosecuted.

Where coloring principles are a desideratum, the adulteration of bread, cake, etc., while not frequent, has been very marked. Possibly all of my hearers may remember the flagrant adulteration of buns and noodles with chrome

yellow which was brought so prominently to the notice of the Philadelphia community several years ago. Dr. Henry Leffmann at that time found 8 grains of lead chromate in a pound of a sample of soup noodles, placed there to give an imitation egg color, and 2 grains of the same poison in each of the tea buns tested by him. Seventy-eight cases of lead-poisoning were reported by Dr. Stewart from eating chrome yellow pound buns, sixty-four of which were directly traced to the use of chrome yellow by two bakers, in the family of one of whom six deaths occurred, and he himself was made seriously ill. Besides this coloring, macaroni has been found to contain saffron, turmeric (which is considered injurious to health), and Martin's yellow, which is poisonous. In vermicelli, pipe-clay and kaolin have been found as adulterating constituents.

In connection with the baking of bread, cakes, etc., and the presence of alum in bread, the question of alum in baking powders is of extreme importance. Alum is added to bad or slightly damaged flour by both the miller and the baker. Its action, according to Liebig, is to render insoluble the gluten, which has been made soluble by acetic or lactic acids developed in damp flour. Hence, it stops the undue conversion of starch into dextrine or sugar. It has been a popular belief for many years that the presence of alum in a baking powder acts injuriously on the human system. This belief is even held by the medical profession, and has been strengthened by the advertisements of certain baking powders which contain other substances, dwelling upon the injurious effects of alum. In contrast to these, Dr. Blyth, the English authority on foods, states that it is a question whether in the moderate doses in which alum is taken in pastry, or bread or cake, the flour of which has been mixed with alum or alum baking powder, it has the slightest appreciable influence on health. He states that he has used it in his family for years without injury, and concludes by declaring that he is decidedly of the opinion that alum in food, in reasonable quantities, is not injurious to health. Mr. C. A. Crampton, the assistant chemist of the Department of Agriculture at Washington, who has made

an exhaustive investigation of baking powders, states: "Whether the absorption of small quantities of alum into the human system would be productive of serious effects is still an open question, and one that careful physiological experiment alone can decide." Finally, Mr. Levi Wells, Dairy and Food Commissioner of Pennsylvania, in his report for 1896, which has just been published, states: "A careful study of the question leads to the conclusion that a properly compounded alum powder will perform all the desired requirements, and is no more harmful than the powders costing four or five times as much." How little weight Mr. Wells places upon the injurious properties of alum salts is shown by his recent decision on the pickle question. In this decision, Mr. Wells states that the use of "alum in pickles is not prohibited. It does not injuriously affect the same, but is added to improve the appearance and quality."

SPICES AND CONDIMENTS.

The various spices and condiments offer a very fertile field for adulteration, in that they come into the market mainly in a very finely divided form. No better example of the extent of such adulteration could be given than the bare statement of the list of adulterants that have been found in the more common spices. Nor are these isolated cases. In the samples examined, and they run into the hundreds, the adulteration is fully 75 per cent. For example, in black pepper there have been found buckwheat flour and ground hulls, cracker crumbs, Indian meal, wheat flour, charcoal, sand, bran, linseed meal, cocoanut shells, mustard husks, sawdust, ground olive stones, cayenne pepper, red clay and ship's bread. Gen. B. F. Butler has alleged that the pepper used to cure hides sent from South America to this country is washed, dried and sold as pure pepper. Mr. Wedderburn, in commenting upon this statement, aptly says: "One can imagine how they would like salt from spoiled fish or decomposed meat. This class of pepper is no better."

In cayenne pepper there has been found red lead, ground

rice, flour, salt, cracker dust, Indian meal, ship biscuit, etc. Cloves contain arrowroot, along with other substances. Cinnamon is adulterated with spent bark, gypsum, rice hulls, turmeric, browned bread and crackers. Ginger contains turmeric, cayenne pepper, mustard, inferior and refuse ginger. Of all the spices and condiments, however, mustard is king, so far as adulteration is concerned. The substances reported as having been found in it include ground yellow cakes, flour, cayenne pepper, chrome yellow, Martin's yellow, gypsum, turmeric, mustard cake colored with turmeric, diluted with starch; wheat and rice flour, weighted with terra alba. Whole mustard contains clover seed, turnip seed and other vegetable seeds.

As regards spices, Philadelphia occupies a rather unenviable position. In 1890, Mr. Frank A. Hennesy reported that there existed in Philadelphia an industry of no small magnitude for the production of articles known to the trade as "spice mixtures;" that these were being made in a large steam bakery in Philadelphia, out of a grade of wheat lower than middlings. The process consisted in baking dough made from this wheat in the shape of biscuits and colored to meet the demands of the special spice it was intended to imitate. For the yellow of mustard, turmeric was used; for brown, the latter with Spanish brown; for black, charcoal. These biscuits were sold to the spice dealers, who "transformed" them into spices.

TEA, COFFEE AND COCOA.

Tea, coffee and cocoa are frequently subjected to adulteration, although since the enforcement of the United States tea adulteration law (1883), the sophistication of this commodity has considerably lessened. The forms of adulteration most commonly practised with tea are facing, the use of spent or exhausted leaves, and the introduction of foreign leaves, foreign astringents, such as catechu, and added mineral matter. The process called facing consists in treating the prepared leaves with mixtures of turmeric, indigo or plumbago to impart some favorite color or gloss to the leaf. Gypsum, soapstone, etc., are likewise used.

Coffee, too, is subjected to facing and coloring, particularly inferior or damaged coffee, for the improvement of its appearance and in imitation of superior grades. For this purpose there have been used yellow ochre, Silesian blue, chrome yellow, burnt umber, Venetian red, drop black, charcoal, French black, glycerine, palm oil, indigo, coal, clay, ultramarine and gypsum. More important is the substitution of coffee by the prepared root of the chicory plant, "mangold-wurzel," peas, beans and saw-dust, various kinds of seeds, cocoa husks, and in particular what is called in Germany, "Kunst Kaffee," or artificial coffee. Within the past few years, our markets have been flooded with these imitation coffees, which are composed in the main of bran, starch, flour, sugar and similar ingredients. Many of these substitutes come from abroad, but American ingenuity has likewise invented machines which enable the manufacturer of spurious coffee to turn out products so closely resembling pure coffee in appearance that its detection with the eye is difficult. Not only has ground and roasted coffee been thus imitated, but even artificial green coffee is on the market, and so close is the imitation that only experts can tell the difference. In 1891, the *Philadelphia Times* brought to the attention of its readers the extent to which this fraud was practised. It showed that immense quantities of what was known as "Java coffee compound" had been distributed throughout Philadelphia and New Jersey, and that the office of one of the manufacturers was within a block of the City Hall.

Cocoa is frequently and systematically adulterated, since it offers conditions so favorable for profitable adulteration. Mr. Spencer states that "there is probably no more misleading or abused term in the English language than the term 'soluble cocoa.' No cocoa on the market contains a very considerable percentage of matter soluble in water, unless the material so dissolved is foreign soluble material that has been added during the process of preparation." The most common form of cocoa adulteration is the extraction of the fat. It is claimed by some manufacturers that this is necessary in order to make the cocoa more readily

digestible. Whether this is the case or not, the public should be made cognizant of the amount of fat which any special cocoa preparation contains. It is impossible within the limits of this lecture to go more fully into the details of the adulteration of these three articles. The index alone to the literature of the subject covers many pages, and each article could by itself consume the time of a lecture without exhausting the subject.

LARD AND OLIVE OIL.

Of great importance to us as food-stuffs are two articles, lard and olive oil. The character of the adulteration practised with these two substances is somewhat limited; the extent of the adulteration seems to know no bounds. With both lard and olive oil, the usual form of falsification is the substitution of the oils and fats which occur in them, by other vegetable or animal oils and fats, in particular by cotton-seed oil. Besides this general adulterant, olive oil has a special adulterant in peanut oil, while lard contains the stearines and oleo-stearines obtained from beef and sheep fats. Finally, to cap the climax, it has been found that water to the extent of 20 per cent. may be worked in with lard, without causing any appreciable difference in its appearance, if an alkali such as carbonate of soda be added at the same time. The extent to which this last adulteration is practised is probably much larger than is generally supposed. The use of cotton-seed oil for the adulteration of both lard and olive oil has grown into a very extensive industry, and it is probable that 75 per cent. of the oil sold as olive oil, salad oil, etc., contains cotton-seed oil to a greater or less extent. Furthermore, it has been definitely proven that cotton-seed oil is shipped from this country to Europe, in bulk, there used to adulterate olive oil, and then returned to these shores labelled as a pure product of the olive.

MOLASSES, SYRUP, HONEY, CONFECTIONERY.

The adulteration of molasses and syrup has already been considered in the foregoing, where it was shown that the bulk of the samples examined contained glucose, or tin salts.

These latter are added for the purpose of bleaching the molasses, and are highly objectionable on account of their poisonous properties. Sulphites and hyposulphites are likewise added for a similar purpose, and are very frequently found in the light-colored New Orleans molasses which comes into our markets. Sugar is an article of food that is rarely adulterated by added matter. Occasional samples show the presence of starch or of minute quantities of ultramarine which has been added to improve the color. Several years ago, an attempt was made to adulterate cane sugar with sugar made from corn starch, but owing to the sticky properties of the latter, the method had to be abandoned. Of low grade sugars, water is the chief adulterant. The modern methods of sugar boiling permit of the introduction of considerable quantities of water without any appreciable difference in the appearance of the sugar.

Honey, like the other food-stuffs that have been mentioned, is frequently adulterated. This is true, however, only of strained honey or of comb honey packed in glass jars, it being almost impossible to adulterate honey that is sold wholly in the comb. When sold as strained honey, or as comb honey in glass vessels, the adulteration practised is of the most glaring kind. The cases are frequent where the honey has been separated from the comb, the latter placed in vessels, covered with glucose, and the mixture then sold as pure comb honey. A thick syrup of cane sugar is also used to adulterate honey, but owing to the tendency which it has to crystallize, it can be used in small quantities only.

It is difficult to say what constitutes adulteration in candy, there being no fixed standard for its composition. The usual conception of candy is a compound made up of saccharine matter, flavoring, and either with or without coloring matter. So long as any of these ingredients is not injurious to health, it can hardly be said that candy is adulterated. The cheaper grades of candy contain, as a rule, commercial glucose instead of cane sugar, starch and a gum, such as gum tragacanth. Occasionally terra-alba and injurious coloring matter obtained from coal tar have been found, but, as a rule, the principal coloring consists of an

organic dye which has no harmful properties. The following is a partial list of the substances found in 250 samples of candy examined by the national Department of Agriculture:

Sucrose, dextrose, maltose, dextrine, starch, gum, gelatine, grease, flour, copper, mineral colors, cochineal, eosin, corallin, Bengal red, fluorescin, ultramarine, turmeric, methyl orange, carmine, lampblack, Victoria yellow, magenta, orange red, aniline brown and Bismarck brown.

CANNED VEGETABLES, CATSUP, JELLIES, ETC.

Under one heading we may consider several groups of food-stuffs, which while different in composition, are alike in the form of adulteration, which is resorted to. These groups include the varieties of canned vegetables, fruit butters, jellies, preserves and catsups. The forms of adulterations, common to all of these, consist in the use of coloring matter, of imperfect vegetables or fruits, of other fruits and vegetables than those called for, of preservatives. In the case of canned vegetables, there is an accidental adulteration from the ingredients of the can, such as lead and tin, and which may, as a rule, be attributed to a lack of care in canning.

In all of the groups mentioned the adulteration practised is of the most flagrant and extensive kind. Catsups are made of skins and cores instead of the pure vegetable, then colored with a coal-tar product and loaded with salicylic acid to prevent fermentation. Fruit butters are nothing but parings and scrapings of fruit, to which glucose, starch and coloring have been added, with salicylic acid as a preservative. Jellies are made from glucose, flavored with essential oils and colored, to which salicylic acid is added. Some fruit jellies marked as pure have never seen a trace of fruit. What is true of jellies is true of preserves. Put together refuse material, the cheapest sort of glucose, some coloring and salicylic acid, and you have the composition of some of the cheaper forms of preserves that are to be found on the shelves of some of our grocery stores. Of these coarser forms of adulterations it will be unnecessary to say

even a word. They are universally recognized as unfit to be used, and every honest dealer is of the opinion that the sooner they are driven out of the market the better it will be for trade. Two special forms of what have been and still are considered adulterations, cannot be so lightly passed over. These are the use of copper salts for greening vegetables, such as peas, and the very extensive use of salicylic acid and allied products for the preservation of the vast bulk of the articles of food above mentioned. Regarding the greening of peas by copper salts, the last word has probably been said. At a conference between the officials of the State and a committee representing the Retail Grocers' Association of Philadelphia, held at Harrisburg, on April 15, 1896, Mr. Finley Acker, of Philadelphia, delivered an address on "Colored French Peas," in which he showed, to the satisfaction of every one present, that the addition of copper salts to peas, in the amount ordinarily used, could exert absolutely no injurious influence on the system.

Mr. Acker showed in detail that during the past forty years, hundreds of millions of cans of French vegetables had been eaten, and that in the entire time there had never been a single well-authenticated instance of poisoning that could be definitely traced to the minute quantity of copper used in preserving. He further showed that copper occurred naturally in bread, wheat, oats and other cereals, meat, wines, water, in the blood and in the organs of man, in quantities at times larger than are found in the peas under discussion. In his address he quoted as conclusive testimony, the investigations of eminent chemists, who subjected themselves and their entire families to a systematic diet of copper salts in their food for a period of years without noticing any injurious effects in the entire time.

As a result of the conference, Mr. Wells handed down his decision that all the department would require on French vegetables would be the distinct labelling "artificially colored," whenever coloring matter is used. This ruling has since been extended to include all canned vegetables, whether imported or domestic.

While, therefore, to-day there is a concensus of opinion regarding the non-injurious effect of copper salts when used in vegetables in judicious amounts, an entirely different view is held regarding the use of salicylic acid, benzoic acid, boracic acid and similar drugs as food preservatives. Notwithstanding the protests of some manufacturers that it is impossible for them to properly prepare their products without the use of such preservatives, it has always been the case that canned vegetables, etc., in good condition and free from added preservative, can be obtained if they are desired. Investigation has furthermore shown that, in many cases, the preservative has been added not to protect good food, but to improve that which is already decomposed and tainted.

There can be hardly any doubt in the mind of the discerning individual, after the conclusive and exhaustive researches that have been made, that the use of preservatives such as have been mentioned, and of salicylic acid in particular, in any quantity whatsoever, should be positively prohibited. More stress is laid upon salicylic acid than upon the others, since this is more commonly used. A single druggist in Columbus, O., reported that he had sold in one season over 500 ounces of the drug, all of which he felt confident had been used for the preservation of food.

It is well known to-day that salicylic acid is a powerful antiseptic. As such it retards the action of organized ferments like the yeast plant and putrefactive bacteria. It hinders and prevents fermentation, the souring of milk and the putrefaction of milk. Its action upon unorganized ferments is even more powerful. It completely arrests the conversion of starch into grape sugar by diastase and pancreatic extracts. This action is directly opposed to the process of digestion, and were there no other reason, the use of salicylic acid should be universally condemned. These facts in connection with salicylic acid have been recognized very thoroughly in legislation. The use of the acid has been condemned by most of the European countries having pure food laws. In France it is forbidden by law. In Austria, Italy and Spain it cannot be used without the danger of in-

curring a heavy penalty, and all South American States having pure food laws have absolutely forbidden its sale. The laws of many of the States forbid its use. By a decision of Mr. Wells, the Dairy and Food Commissioner, the use of salicylic acid in foods is prohibited in Pennsylvania.

I wish to call attention here to another fact in connection with the use of salicylic acid, which is of extreme importance, viz.: the sale of preservalines, preservatives, etc., under various high sounding names, intended for use in private families. A number of these, claimed to be perfectly harmless, are on the market, but actually contain salicylic acid as the main ingredient. The conscientious and careful housekeeper should put an absolute veto upon the use of any such compound. There is rarely any need for them, since when pure fruits and vegetables are used, and the proper directions for sterilizing by heat, etc., are carried out, canned or preserved goods of all descriptions can be prepared that will remain in good condition for years without the aid of any preservative.

Of the more common food-stuffs still to be considered, are:

VINEGAR, BEER AND WINE.

All three of these are extensively adulterated. With vinegar, the main form of adulteration is the addition of water and the consequent lessening of the acidity and of the total solids which a standard vinegar contains. In Pennsylvania, the standard for cider vinegar is an acidity of 4 per cent. and 2 per cent. of solids. Besides this practice, the sale of spirit vinegar, colored with caramel, for pure cider vinegar is very common, and in fact until the enforcement of our stringent law, there was very little pure cider vinegar on the market. White wine vinegar is likewise frequently a delusion. In its place there is sold the distilled vinegar obtained from grain. This grain or spirit vinegar, even when sold for what it is, is frequently adulterated by the addition of water. The vinegar law, as at present constituted, makes no standard for any vinegar other than cider vinegar, and hence it is impossible to define

what constitutes a standard spirit vinegar. This feature of the law makes the entire statute very objectionable, and it is probable that at the present session of the Legislature a new law, drafted by Deputy Commissioner Moore, of the Food Department, will be introduced to remedy this evil.

Regarding wine and beer, but little can be said at present. In this State no standards have been set up as to what shall constitute the pure article. If beer and other malt beverages should consist solely of the product of malt and hops, then the addition of burnt sugar, licorice, treacle, quassia, coriander and caraway seed, cayenne pepper, soda, salicylic acid, salt, grains other than barley malt, is certainly adulteration.

Wine has been adulterated from the very earliest times. It is hardly necessary for me to say that the same condition of affairs exists to-day. Fortification with alcohol, the use of coloring principles, the addition of acids, and even worse forms of adulteration—such as the addition of refuse matter that will ferment—are frequently resorted to. The entire subject of liquid food and nourishment offers a very fertile field for investigation by the authorities, and must eventually end in the framing of a law which will define what shall constitute adulterations in these articles.

Before bringing this lecture to a close, I trust you will allow me a few minutes for a discussion of the Pure Food Law as it exists in Pennsylvania. Nineteen months have passed since the law was framed, and in that time it has met supporters and detractors without number. Reputable merchants, as a rule, have given it their support and have endeavored to conduct their business according to its requirements. Of all the blows which have been levelled at it, possibly the worst, so far as immediate results are concerned, is the recent decision of Judge Hemphill, of Chester County, declaring the law unconstitutional. In order to appreciate this decision more thoroughly, permit me to quote a few passages of the act of June 26, 1895, entitled, "An act to provide against the adulteration of food, and providing for the enforcement thereof." Section 1 of this act reads: "Be it enacted, etc., that no person shall, within

this State, manufacture for sale, offer for sale or sell any article of food which is adulterated within the meaning of this act."

Section 2 reads: "The term food, as used herein, shall include all articles used for food or drink by man, whether simple, mixed or compound—

Section 3 reads: "An article shall be deemed to be adulterated within the meaning of this act—"

"(*a*) In the case of food: (1) If any substance or substances have been mixed with it so as to lower or depreciate or injuriously affect its quality, strength or purity. (2) If any inferior or cheaper substance or substances have been substituted wholly or in part for it. (3) If any valuable or necessary constituent or ingredient has been wholly or in part abstracted from it. (4) If it is an imitation of or is sold under the name of another article. (5) If it consists wholly or in part of a diseased, decomposed, putrid, infected, tainted or rotten animal or vegetable substance or article, whether manufactured or not, or in the case of milk, if it is the product of a diseased animal. (6) If it is colored, coated, polished or powdered, whereby damage or inferiority is concealed, or if by any means it is made to appear better or of greater value than it really is. (7) If it contains any added substance or ingredient which is poisonous or injurious to health: Provided, that the provisions of this act shall not apply to mixtures or compounds recognized as ordinary articles or ingredients of articles of food, if each and every package sold or offered for sale be distinctly labelled as mixtures or compounds and are not injurious to health."

Judge Hemphill's decision of the unconstitutionality of the law rested on Clause 2 of Section 3, which refers to the substitution wholly or in part of any inferior or cheaper substance for the food in question. The learned Judge contended that substitution was not the same as adulteration, and since there is no mention of substitution in the title of the act, the act violated the organic law of the Commonwealth, which requires the particulars of any section of an act to be nominated in the title. Unfortunately for the Pure Food Law, there is hardly any question that Judge

Hemphill is correct from the legal standpoint, and the case offers but another illustration to many that have gone before of slipshod methods of legislation notwithstanding the presence of considerable legal talent in our legislature. Unquestionably, this section of the act will require revision and amendment.

Possibly other sections may require similar treatment. For example, Section 2 states that "the term food as used herein shall include all articles used for food or drink by man. * * *" This section is a counterpart of the English law on the subject, and yet in England it has been decided that under this clause baking powders could not be included. Judge Hawkins, in rendering his decision, stated that "the mere sale of an article, not in itself an article of food, even though it be sold in the knowledge of the vender, that it is the buyer's intention to mix with it the ingredients of which an article of food, *e. g.*, bread, is to be composed, is no offence under Section 3, and it makes no difference, in a legal point of view, that when sold it is mixed with other ingredients not in themselves hurtful, some or one of which might in an unmixed state be used as articles or an article of food, if the injurious and harmful articles are so inseparably mixed and in such quantities as that the mixture as a whole forms an injurious compound which no one would dream of using as a food." Referring to the baking powder in dispute, Judge Hawkins said: "Who would venture to describe such a mixture (sodium bicarbonate, 20 per cent.; alum, 40 per cent.; ground rice, 40 per cent.) as the food of man? With equal truth might not powder composed of poison mixed with flour be called food for man because pure flour is used? Possibly it may be said that the injurious ingredients, when mixed with other materials of which an article of food is composed, become a part and parcel of such article, but that is no argument against the vender of such injurious ingredient, unless such injurious ingredient can be treated as an article of food at the time of the sale. That is the moment when the test of its character is to be applied, and if it is not then an article of food, no offence is committed by the vender of it, though the purchaser or

any one who afterwards mixes it with an article of food intended for sale, would be guilty of an offence."

This is but one illustration, but it suffices to show that astute legal minds could possibly detect other flaws in our present law. For this reason, it is well that decisions such as Judge Hemphill's should see the light of day; for, while their immediate effect is baneful, their ultimate outcome will mean the revision of the law in such a form that it will be impregnable.

Aside from possible flaws, the law as it stands has received opposition from other sources. The manufacturer, the dealer and the retailer has each, in his turn, found some clause that was obnoxious, some section that interfered with his business interests. Without going too minutely into details, it is conceded even by those who recognize the beneficial value of a pure food law for the honest tradesman, and notwithstanding the liberal policy that has been the invariable rule of the Dairy and Food Commissioner, that it is an impossibility to comply with the letter of the law in its present form. If it were the retailer only who complained, or the dealer, or the manufacturer, or any two of these, it might be supposed that any existing fault in the law would be special in its nature. The fact that the complaint is general, leads to the inference that the fault is organic.

To my mind, the inherent error of the law lies in the absence of a thought which should always be present in legislation of this kind, the underlying idea that a distinction must be made between adulteration that is the result of fraud or negligence and that which arises notwithstanding the fact that every possible precaution to prevent it has been exercised; in other words, the distinction between adulteration wilfully and deliberately planned, and adulteration the result of an accident beyond the power of man to prevent. Countries older in food legislation than we are have recognized this distinction, and have incorporated it in their laws and even in the punishment imposed for their infraction. In Germany, for example, where every detail of food adulteration has been worked out to a nicety,

and where the punishment imposed for the violation of the statutes is severe, the law distinguishes between adulteration prejudicial to health and that which is not. In the latter case, it is first necessary to establish guilty knowledge on the part of the vender before punishment can be imposed. Where substances injurious to health are used, punishment is imposed; and should death result from the use of such substances, the imprisonment may be for a term of five years. In the case, however, where the toxic nature of the substance was known to the vender, the punishment is imprisonment for ten years, and in case of the death of the user, the seller may be imprisoned for life.

After what has been mentioned, it will hardly be profitable to discuss more thoroughly our food law or its administration. The authorities, as must be plainly seen, have no volition in the matter, but are compelled to enforce the law and to prosecute adulterations under the law, as defined in the act which regulates the duties of the Commissioner. Possibly no better proof of the inadequacy of the law could be given than the fact that, notwithstanding the exceptionally humane policy of the Commissioner, and his desire to be not only just but merciful in his decisions, the law has in several cases been a positive source of injury to unintentional offenders, who desired nothing more than to be honest and conscientious in their dealings.

But little more remains to be said. As to what shall constitute the responsibility of the State and the duty of the individual must be left for a more explicit law to decide. In general, it may be stated that the State must eventually recognize that its responsibility does not end with a mere police surveillance and the means necessary to accomplish this one function. It will finally be seen that it is within the province of the State to branch out on the broader lines of educating the community up to the standard which it imposes in its laws. That this will entail expense is without question, but this is a problem that will not admit of the consideration of cost. For the proper development of a food law much is needed—a competent corps of officials; a thorough-working system; an efficient and suitably con-

structed laboratory and appurtenances for the purposes of investigation and research: the dissemination of the results of these researches, so that they reach every individual interested; all these constitute the legitimate work of the State, and should be so recognized. When this is once accomplished, and when the law is so framed that the ethical idea of a distinction between deliberate and unintentional wrongdoing is incorporated as one of its bulwarks, on that day every one will acknowledge that a pure food law has more influence in protecting the health of the community, in benefiting trade, and in inculcating the doctrines of social and moral order, which are the mainstay of the State, than has any other statute in the laws of the Commonwealth.

TRANSVERSE STRENGTH OF CHILLED CAR WHEEL METAL AS AFFECTED BY THE RELATIVE DIRECTIONS OF STRESS AND CHILL. WITH SOME NOTES ON THE CHEMISTRY OF CAST IRON.

By Asa W. Whitney, Member of the Institute,
Metallurgical Engineer for A. Whitney & Sons' Car Wheel Works.

The peculiarities of the cast iron suitable for any one class of work, notably for chilled cast iron car wheels, are inviting subjects for study, because the material is not only complex and in general sensitive to chemical and physical conditions, but also because little has been published explaining the anomalies revealed by chemical analysis.

Therefore, in presenting a novel physical feature of chilled iron, I wish to call attention to the fact that the complications of the subject have been taken into account, and that though my report deals with but a small number of test bars, none of which were analyzed, I know that they are practically of the same general class of material. That is to say, that though it is hardly possible that there are even two bars in the whole lot of identically the same analysis,

yet long experience with chemical and physical tests of this kind of cast iron, and particularly the calculated chemical composition of the cupola charge in the case of series I, assure me that the compositions are all good wheel mixtures, and that even the considerable differences shown between the two series (I and II) do not amount to a difference in kind of metal, but merely to degree in quality of the same kind of metal. The phenomena noted are therefore due to the relations of stress and chill, and, as a matter of fact, show to a considerable extent in cast iron suitable for purposes other than chilled castings (see *Fig. 9*).

In noting some of the complications referred to above, I would first remark that the element iron is usually slighted in reports of analyses of cast iron, evidently because it does not vary proportionately so much as the other elements, being usually 92 to 97 per cent. of the weight of the substance. Thus it is usually necessary to calculate its percentage by difference (100 — sum of other elements = iron), which throws an undue amount of analytical error upon the figure representing the iron. The value of very exact analyses in certain cases will be appreciated only when the meaning of chemical differences in composition has become a subject of closer study generally for practical purposes. A series of graphical tabulations, elaborated from reports of analyzed physical test bars of A. Whitney & Sons' wheel and other mixtures, by Wm. R. Webster, C.E., shows plainly the potent influence of relatively small variations in amounts of iron present.

Many other points are shown by a close study of this valuable work, though at first sight of its irregularities it would appear that no better proof need be sought to show the unreliability of chemistry of cast iron. It was this complication of the subject, particularly in hard iron, that necessitated five years of practical analysis, experiment and study on the part of the writer, previous to 1889, to get an insight into such and other fundamental principles governing the constitution of cast iron, which have made possible a very practical use of its ultimate chemical analysis. Even had the writer never justified his methods of iron mixing

FIG. 1.

FIG. 2.

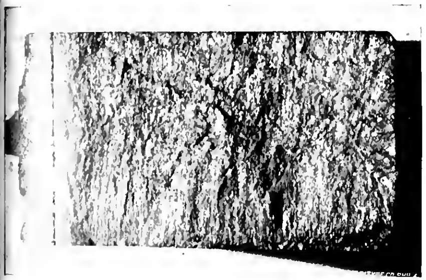

FIG. 3

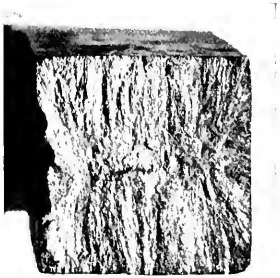

FIG. 5.

FIG. 4.

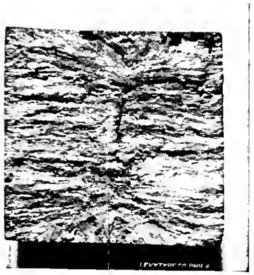

FIG. 6

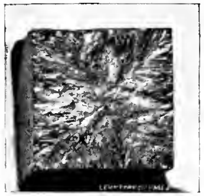

FIG. 7.

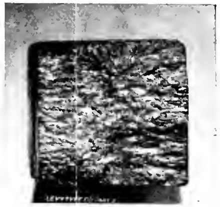

FIG. 8.

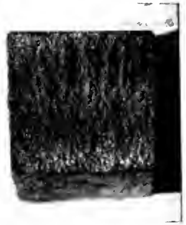

FIG. 9.

CROSS SECTIONS.

Fig. 1.—Test bar for cast-iron wheel mixture, cast in all sand mould.

Fig. 2.—Chill test of same iron, one side cast against iron block.

Fig. 3.—Test bar of same iron, same volume and area as No. 1, but chilled on wide sides.

Fig. 4.—2″ square test bar. Chilled on the four sides. Same volume and area as No. 1. Same sort of iron.

Figs. 5 and *6.*—1½″ square bars, same iron. Chilled on two opposite sides.

Fig. 7.—1″ square ingot, 4″ long. Four sides chilled.

Fig. 8.—1″ square test bar. Chilled on two opposite sides.

Fig. 9.—Strong, soft iron, 1″ square bar. Chilled on two opposite sides.

Fig. 10.—A gray pig, white in center. Ultimate composition of gray and white remarkably alike.

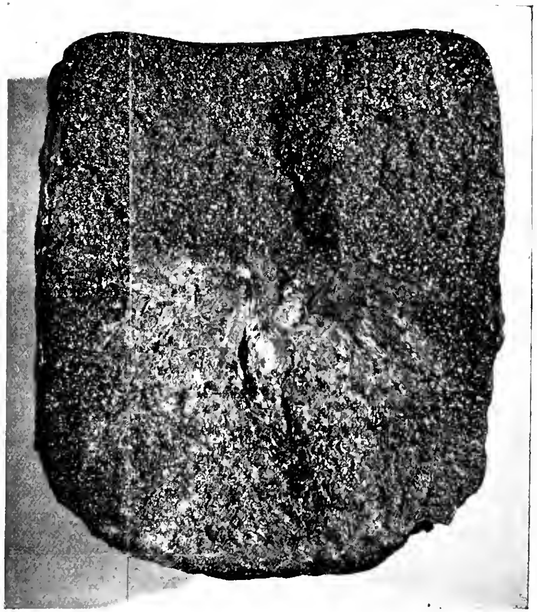

FIG. 10.

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for specified quality by success and economy while working on those principles without any tabulation, these present tables are sufficient to vindicate his working theory. Beside the satisfactory and economical regulation of the quality of castings by calculations of chemical compositions of cupola charges, it naturally follows that the data and studies on compositions now collected indicate the practicability of a really accurate prediction of strength, chill and shrinkage under given conditions from the actual analysis of the casting, test piece, or even of water-chilled shots. Some success has already been attained by the writer in this direction by following out some original conceptions based on the principles already practically applied in the calculation of cupola charges for our various purposes. In the determination of strength, from the ultimate analysis, I have been aided by a rough but suggestive table, also arranged early in 1896, by my assistant, Mr. C. F. Fisher, who, though in 1890 was skeptical of the feasibility of the close application of chemistry to our cupola work, became interested in the matter as its success became apparent.

Though the least understood, the most valuable characteristic of cast iron is in reality its apparently anomalous behavior in reference to chemical composition. For instance, one finds that certain compositions, widely different in figures, are, to a valuable extent, chemically equivalent, in that they suffice to produce practically identical physical attributes in the casting. To properly grade iron by analysis in a manner equivalent to the convenient grading by fracture, this point must be appreciated. The present grading is, in general, fundamentally correct, and the chemist must learn it and then subdivide and classify it.

The above statement, however, does not contravene the fact that certain compositions, erroneously assumed to be "practically identical," are hardly to an approximate extent suitable for the same purpose. Every founder finds cases of this kind and chemists have been studying them.

In considering the above points, which have shaken the faith of many investigators in the value of the ordinary ultimate chemical analysis of cast iron, one must not lose

sight of the fact that various sorts of compositions differ not only in the *degree* to which they are affected by physical circumstances, but also are in some cases chemically affected in an *opposite manner*, which determines a reversal of ordinary phenomena, causing an appearance of liquation or segregation. But a segregated mass differs decidedly in ultimate analysis from the matrix in which it occurs; while in the cases of reversal of ordinary phenomena the differences in the ultimate constitution of the physically different parts are usually no greater than that occurring frequently in an apparently homogeneous casting. Taken alone, these peculiar compositions are inscrutable, but when tabulated along with certain other compositions in the manner of our tabulations before referred to, they will presumably be found in natural relations to compositions of more frequent occurrence.

But very possibly, before such laborious tabulation is carried much further, the developments of the rather crude formulæ, now useful to the writer in investigating chemical compositions for physical properties, particularly strength and chill, will reveal this tendency accurately.

The "opposite" chemical effect mentioned above consists in the carbon remaining in the combined state in the center of the pig or casting, while separating elsewhere in a freer form, sometimes causing almost as open a grain as a No. 1 foundry iron, but brighter. The white, sometimes very hard, crystalline spot frequently covers one-half or two-thirds of the area of the cross-section. Ordinarily, as is well known, hardening or chilling of cast iron is favored by the more rapid cooling at the surfaces, the metal becoming less dense and more graphitic toward the center.

The following are a few of these peculiar compositions:

	One Pig.		*One Pig.*		*One Pig. White and Gray Average.*
Analysis.	*White No. 866.*	*Gray No. 867.*	*White No. 53 T.*	*Gray No. 52 T.*	*No. 1878.*
Total carbon	4·181	4·775	4·255	4·339	4·066
Silicon	·161	·181	·122	·193	·183
Manganese	·609	·518	1·016	1·027	·260
Phosphorus	·328	·332	·273	·253	·037
Sulphur	·010	·010	·010	·010	·021
Iron (by difference)	94·711	94·184	94·324	94·178	95·433
	100·000	100·000	100·000	100·000	100·000

These analyses are, unfortunately, not so scientifically accurate in the matter of sampling and in the sulphur and iron determinations as to make them of the maximum value for study and derivation of formulæ, as they were made mainly for immediately practical purposes. *Fig. 10* shows the appearance of pig like Nos. 52 T and 53 T.

The remelt of such peculiar metal shows the same phenomena as the pig, if not sufficiently altered in composition by admixture of other sorts of metal or by oxidation while melting. Sometimes even a thin casting will be found hard and white in the center, while gray or mottled outside. This is most pronounced where it occurs with silicon about 2·5 per cent., and less carbon than in the above cases.

I understand that none of the attempts to account for this by the detection of unusual elements have been successful. As an evidence that such, as well as other better known, characteristics of cast iron are due primarily to the ultimate constitution, I instance the fact that even such metal is perfectly safe to use in mixtures if the calculations are skilfully based upon the relative values of the elements as units, rather than upon the physical character which their peculiar but easily destroyed proportions have made possible. The physical characters of the component brands of a properly made mixture are "dead issues," as the creation of the desired quality in cast iron results from a combination of the elements in obedience to principles governing its ultimate constitution under the given conditions.

To those who are familiar with chemistry in other departments of art or science, it no doubt appears superfluous to insist that the qualities of charcoal iron, for instance, can be attained whenever its ultimate constitution can be properly attained, whether the elements be contained in coke iron or anthracite iron. But the superstitions of the foundry die slowly, and there is good reason in many cases, as certain qualities are very difficult to regulate. But both strength and chill depend entirely (under given conditions) upon the ultimate constitution.

37,700 lbs. tensile strength per square inch from center of half of a 2-inch square bar, 1 foot long, is the best test I

know of in coke iron, but I have no doubt it can be surpassed. That bar was cut from center of a large pig. The bar itself broke at 29,800 lbs. = modulus of rupture, 67,050, and its resilience was 186·81, which exceeds that of any iron I have tested.

It is interesting to note that this high resilience agreed, as it usually does, roughly, with the impact test of breaking the pig, by throwing violently across a heavy iron breaking-block. An ordinary pig required about five or ten times as much labor as usual to break it, and bounded up from block far more than usual. The resilience referred to in this case and in the table is obtained by the well-known formula,

$$\frac{\text{Stress x Length}}{\text{2 x Weight of bar in lbs.}}$$

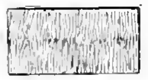
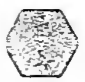
This iron would chill from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch or more, according to method of remelting. Moreover, the writer has made many mixtures of from 30,000 to 40,000 lbs. tensile strength from the poorest material. The shrinkage was low and the working qualities good, and in many cases excellent, with high transverse strength and resilience. No records of the irons and grades are referred to in repeating such results, but merely the chemical calculations and previous physical tests.

By the old way of mixing metal by estimation from physical characters, even with the aid of some partial analysis, the founder is limited seriously in the range of metal safe to use and in the range of mixtures possible to produce. Moreover, to reproduce a closely specified quality from new but apparently similar material to that formerly employed is sometimes a matter of several expensive trials.

By the new way the trial mixtures of analyzed material are made on paper and carefully studied out in reference to the foundry conditions, and adjusted until the maximum quality at the minimum cost is assured. The principles of the matter become continually more apparent, as former results are not lost, but are exceedingly valuable, though consisting merely of a record of calculated chemical cupola charges and a few simple but methodically made physical

SERIES I.

TEST BARS OF CHILLED (SOLID WHITE) CAST IRON CAR WHEEL MIXTURE. CAST IN COMPOSITE MOULDS OF IRON AND SAND. TWO OPPOSITE SIDES ONLY ARE "CHILLED." THE CUPOLA CHARGES CALCULATED AS USUAL BY A. W. WHITNEY BY REFERENCE SOLELY TO THE ANALYSES OF THE MATERIALS AND THE DAILY PHYSICAL TESTS OF THE CAST METAL.

Special Mark.	Position of Chill Crystals. (*Stress vertical.*) Dimensions. *b* = Breadth. *d* = Depth.	Approximate Hardness by Chill Tests.	Contraction in 1/100 Inch per Foot.	Modulus of Rupture or Relative Trans. Strength.	Resilience—Inch Pounds per Pound of Metal (= Impact Test).	TREATMENT. *R* = "Rumbled." *h* = Heavily. *l* = Lightly.	DETAIL. Factor for Modulus.	Breaking Load.	Deflection.	REMARKS. Length 12″ Between Supports. Freely Supported. Cast March 19, 1896.
							(Normal — 5·333)			
A	 *b*, 1·470″ *d*, 1·500″	1″	·22″	52165	47·6	Not *R*.	5·3782	9700	·0718″	Cast from same hand ladle of iron at nearly same time as No. 2. Broken August 20th, after 152 days' rest in office. Middle of Melt.
Ax	 *b*, 1·490″ *d*, 1·493″		·22″	48780	49·2	*R*. 2 hours *l*. along with *Bx*.	5·420	9000	·0798″	(All bars perfect but *Bx*. All heavy mixture.)
No. 2	 *b*, 2·666″ *d*, 1·500″	1″	·21″	47700	49·1	Not *R*.	3·000	15900	·080″	"Regular" bar cast with *A* and *Ax*. Broken next day.
No. 3	 *b*, 2·666″ *d*, 1·500″	¾″	·22″	53100	60·1	Not *R*.	3·000	17700	·088″	"Regular" bar. End of Melt. Cast with *B* and *Bx*. Broken next day.
b	 *b*, 1·493″ *d*, 1·490″	¾″	·23″	33025	23·4	Not *R*.	5·504	6000	·0570″	See No. 3 Remark. But broken August 20, 1896, with *A* and *Ax* and *Bx*.
bx	 *b*, 1·495″ *d*, 1·510″		·24″	26408	14·0	*R*. 2 hours *l*. along with *Ax*.	5·281	5000	·0410″	See No. 3 Remark. 2 per cent. Small in center.
Hex. No 3	 4″ area Side, 1·2408″	¾″	·15″	53280	104·2	Not *R*.	2·22	24000	·111″	Same iron as No. 3, but cast in sand. Solid gray.
Average of *A*, *Ax*, *No. 2*, *No. 3*		·94″	·22″	50436	51·5	Stress applied in the direction of chill crystals.				
Average of *A* and *Ax*		1″	·22″	50473	48·4	Stress applied in the direction of chill crystals.				
Average of *b* and *bx*		¾″	·235″	29717	18·7	Stress applied vertically to direction of chill crystals.				
Average of the four bars in the strong position differs from average of the two bars in the weak position by		Per Cent. + 25	Per Cent. — 7	Per Cent. 69·7	Per Cent. + 175·4	And the Rumbling had little or no effect on this iron.				

Comparing No. 2 with average of *A* and *Ax* indicates a gain of 6 per cent. in strength and a loss of 1·5 per cent. in resilience. This may be due to the 152 days' rest, as 10 per cent. gain in strength by one year's rest has been noted by the writer in soft iron 1″ square test bars, duplicates of which without rest rumbling improved 30 per cent. in one and one-half hours.

Calculating from the above, for a 1″ square bar 12″ long (in the strong position) the breaking load for average of *A*, *Ax*, No. 2 and No. 3 = 2,802 pounds, and for average of *B* and *Bx*, also in a 1″ square bar 12″ long (in the weak position) = 1,651 pounds.

A former case (March 28, 1895,) of A. W. & S. similar wheel mixture cast and tested in same manner as above, but approximately 1″ square section in duplicate bars and measured as above, showed, in the strong position, a modulus of 46,836 pounds = 2,602 pounds on exact 1″ bar with resilience = 28·2, while duplicate in weak position = modulus 24,085 = 1,339 pounds on exact 1″ bar with resilience 7·28. The gain in strong position over weak position = 94·4 per cent. in transverse strength and 287·4 per cent. in resilience. Also 103 per cent. in calculated tensile strength, the cohesion between layers of chill crystals being 13,122 pounds and longitudinally in crystals 27,038 pounds per square inch. Direct experiment here has shown the tensile strength transversely to chill crystals to vary from about 13,000 to 18,000 pounds. No tensile test of chill longitudinally has yet been made.

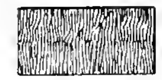
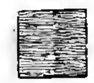
Note that the maximum transverse strength of the chilled metal is nearly as high as that of the same iron cast totally gray in sand. But that the resilience is only about half that of the gray metal. This is not unusual. Crushing strength weak way = 150,000 to 200,000 pounds. No test in the strong way.

The normal size of No. 2 and No 3 bars is assumed, as they are not measured in our daily practice, but they are always a trifle under size, like the 1½″ bars, therefore results are not too high. Like hexagon gray bar, the cross-section is 4 square inches and solidity 48 cubic inches between supports.

The 1½ square inch bar	= 2·25 square inches in cross-section and weighs	7·3 pounds	= 27 cubic inches	specific gravity at	7·484
" Rectangular "	= 4·00 " " " " " "	12·95 "	= 48 "	" " " "	7·467
" Hexagon (gray)	= 4·00 " " " " " "	12·6 "	= 48 "	" " " "	7·266

SERIES II.

TEST BARS OF CHILLED (SOLID WHITE) CAST IRON CAR WHEEL MIXTURE. SIMILAR IN EVERY RESPECT TO [illegible] THE CUPOLA CHARGES ARE CONTROLLED BY EXPERT JUDGMENT OF FRACTURE AND OCCASIONAL [illegible] OF BOTH THE MATERIAL AND THE CAST METAL.

Special Mark.	Position of Chill Crystals. (*Stress Vertical.*) Dimensions. *b* = Breadth. *d* = Depth.	Hardness Represented by Chill Tests.	Contraction in 1/100 Inch per Foot.	Modulus of Rupture or Relative Trans. Strength.	Resilience—Inch Pounds per Pound of Metal (= Impact Test.)	TREATMENT. *R* = "Rumbled." *h* = Heavily. *l* = Lightly.	Factor for Modulus.	Breaking Load.	Deflection.
A	 *b*, 1·499″ *d*, 1·515″	½″	·24″	47185	42·2	*R*. ½ hour *l*.	5·243	9000	[illegible]
B	 *b*, 1·518″ *d*, 1·497″	⅝″	·25″	47970	42·9	*R* 3 hours *h*.	5·292	9000	[illegible]
C	 *b*, 1·488″ *d*, 1·508″	⅝″	·23″	50010	46·3	Not *R*.	5·320	9400	[illegible]
H	 *b*, 2·667″ *d*, 1·478″	⅞″	·23″	45050	49·9	Not *R*.	3·044	14800	·0870″
L	 *b*, 2·666″ *d*, 1·490″	¼″	·22″	41050	36·5	Not *R*.	3·041	13500	·0800″
a	 *b*, 1·503″ *d*, 1·529″	½″	·22″	25615	16·4	*R*. ½ hour *l*.	5·123	5000	·0479″
b	 *b*, 1·516″ *d*, 1·462″	⅝″	·25″	26665	15·0	*R*. 3 hours *h*.	5·555	4800	·0450″
c	 *b*, 1·496″ *d*, 1·478″	⅝″	·22″	23985	14·1	Not *R*.	5·508	4500	·0456″
Average of *A*, *B*, *C*, *H*, *L*		·575″	·23″ +	46253	43·6	Stress applied in direction of the chill cry			
Average of *A*, *B*, *C*, *H*		·631″	·24″ —	47554	44·6	Stress applied in direction of the chill cry			
Average of *A*, *B*, *C*		·583″	·24″	48388	43·8	Stress applied in direction of the chill cry			
Average of *a*, *b*, *c*		·583″	·23″	25422	15·2	Stress applied vertically to direction of th			
Average of the four bars *A*, *B*, *C*, *H*, in the strong position exceeds average of the three bars *a*, *b*, *c*, in the weak position, by		Per Cent. + 8·3	Per Cent. + 4·4	Per Cent. + 87·1	Per Cent. + 193·5	And the Rumbling evidently had little or			

SUMMARY I AND II.

Average of 9, strong position	·625″ = ⅝″	·226″	48112	47·1	
Average of 5, weak position	·650″ = 21/32″	·232″	27140	16·6	
	Per Cent. — 3·8	Per Cent. — 2·6	Per Cent. + 77·3	Per Cent. + 183·8	Gain or loss in strong position over weak

SERIES II.

[…]) Cast Iron Car Wheel Mixture. Similar in Every Respect to Bars of Series I, Except that [they] are Controlled by Expert Judgment of Fracture and Occasional Physical Tests of Both the Material and the Cast Metal.

[…] by Chill Tests.	Contraction in 1/10 Inch per Foot.	Modulus of Rupture or Relative Trans. Strength.	Resilience—Inch Pounds per Pound of Metal (= Impact Test.)	Treatment. R = "Rumbled." h = Heavily. l = Lightly.	Detail. Factor for Modulus.	Breaking Load.	Deflection.	Remarks. Length 12" between supports. Freely supported. Cast September, 1896.
[…]2"	'24"	47185	42'2	*R.* ½ hour *l.*	5'243	9000	'0684"	All bars perfect but *L*. *H* and *L* are A. W. & Sons' regular form. All bars other than *L* are same sort of mixture as *H*, cast on three other days. Same letter indicates same iron dipped up from large ladle at same time by two hand-ladles and poured alike.
[…]5"	'25"	47970	42'9	*R* 3 hours *h.*	5'292	9000	'0695"	
[…]"	'23"	50010	46'3	Not *R.*	5'320	9400	'0718"	
[…]"	'23"	45050	49'9	Not *R.*	3'044	14800	'0870"	Mixture for heavy wheels.
[…]4"	'22"	41050	36'5	Not *R.*	3'041	13500	'0800"	About 3 per cent. of minute cold shots all over. Mixture for light wheels. This is the only bar not solid white, gray center ¼" wide.
[…]4"	'22"	25615	16'4	*R.* ½ hour *l.*	5'123	5000	'0479"	
[…]8"	'25"	26665	15'0	*R.* 3 hours *h.*	5'555	4800	'0456"	
[…]"	'22"	23985	14'1	Not *R.*	5'508	4500	'0456"	
[…]5"	'23"+	46253	43'6	Stress applied in direction of the chill crystals.				
[…]31"	'24"—	47554	44'6	Stress applied in direction of the chill crystals.				
[…]33"	'24"	48388	43'8	Stress applied in direction of the chill crystals.				
[…]3"	'23"	25422	15'2	Stress applied vertically to direction of the chill crystals.				
[…]Cent. […]8'3	Per Cent. + 4'4	Per Cent. + 87'1	Per Cent. + 193'5	And the Rumbling evidently had little or no effect.				

SUMMARY I AND II.

= 7/8"	'226"	48112	47'1	
= 31/32"	'232"	27140	16'6	
[…]Cent. 3'8	Per Cent. — 2'6	Per Cent. + 77'3	Per Cent. + 183'8	Gain or loss in strong position over weak position.

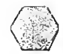
TESTS OF TRANSVERSE STRENGTH OF CHILLED WHEEL IRON. EFFECTS OF DIRECTION OF CHILL. SUMMARY SERIES I AND II.

I = A. Whitney & Sons' wheel iron. II = another founder's wheel iron. March and September […]

Comparisons referred to modulus of rupture or relative transverse strength.

Strong position.   Weak position

Stress vertical.

	Series.	Number of Tests.	Special Marks.	Kind of Bar. Cross-section. Inches. d. b.	Chill Tests. Inch.	Contraction in 12 Inches. Inch.	Modulus of Rupture or Relative Transverse Strength.	Weight for 1-inch Square Bar.	Resilience. Inch Pounds per Pound of Metal.	Remarks. R = […] h = hea[vily] […]
Maximum results in the strong position	I II	4 5	No. 3 *C*	1½ x 2⅔ 1½ x 1½	¾	0'22 0'23	53,100 50,010	2,[illegible] 2,[illegible]	[illegible] 46'3	Not *R.* Not *R.*
Minimum results in the strong position	I. II	4 5	No. 2 *h*	1½ x 2⅔ 1½ x 2⅔	1 ¾	0'21 0'23	47,700 45,050	2,650 2,50[illegible]	49'1 [illegible]	Not *R.*
Maximum results in the weak position	I II	2 3	*b* *b*	1½ x 1½ 1½ x 1½	¾ [illegible]	0'23 0'25	33,025 26,665	1,[illegible] 1,452	23'4 15'[illegible]	Not *R.* *R.* 3 hours *h.*
Minimum results in the weak position	I. II.	2 3	*bx* *c*	1½ x 1½ 1½ x 1½	¾ [illegible]	0'24 0'22	20,408 23,935	1,467 1,330	14'0 14'1	*R* 2 hours […] Not *R.*
Average results in the strong position	I. II	4 4	*A. Ax* Nos. 2 & 3 *A B C H*	1½ x 1½, 1½ x 2⅔ 1½ x 1½, 1½ x 2⅔	0'94 0'63	0'22 0'24	50,436 47,554	2,[illegible] 2,[illegible]	51'5 44'6	Not *R.* *C* & *H* Not […]
Includes one softer bar not completely chilled of a mixture for lighter wheels	I and II	[illegible]	5 4	Square. Rectangular.	0'63	0'23	48,112	2,[illegible]	47'1	—
Average results in the weak position	I. II I and II	2 3 5	*b, bx* *a b c* *a b c*	1½ x 1½ 1½ x 1½ 1½ x 1½	0'75 0'58 0'65	0'24 0'23 0'23	29,717 25,422 27,140	1,[illegible] 1,41[illegible] 1,50[illegible]	1[illegible] 15'2 16'6	See above *a* *R.* ½ hr. *b* *R.* 3 hrs. *c*. Not *R.* See above.
Average results in weak position being taken as 100, average results in strong position show difference by percentage of + or —.	I. II I and II	— — —	— — —	— — —	Per Cent. + 25'[illegible] + 8'3 — 3'8	Per Cent — 7'[illegible] + 4'4 — 2'6	Per Cent. + 69'7 + 87'1 + 77'3	— — —	Per Cent. 175'4 + 193'5 + 183'8	It is evident the rumbling […] little or no effect […] this solid white […]
Compare the same iron as No. 3 in Series I, cast in sand in hexagon form, 4-inch area section, same as No. 3 chilled bar (Totally gray.)	No. 3 hexagon bar. Gray.	1	Hex No. 3	 Side. 1'2408	Inch ¾	Inch. 0'15	53,280	2,060	1[illegible]2	Not *R.*
3/28/'95, A. W. & Sons' wheel iron cast approximately 1 inch square, but measured See *Fig.* 8.	Strong position.	1	1 in. sq.		1	—	46,830	2,[illegible]	23'2	Not *R.*
	Weak position.	1	1 in. sq		—	—	24,[illegible]85	1,33[illegible]	[illegible]	Gray hexagon […] of same iron […] inch contraction
The average results of Series II being taken as 100, the average results of Series I show a difference by percentage of + or —.	Strong.	4 to 4	See above.		Per Cent. + 49'0	Per Cent. — 8'4	Per Cent + 6'06	—	Per Cent. 15'5	General average 18'2 per cent. in favor of Series I. All are heavy wheel mixtures. Bars totally white
	Weak.	3 to 2	See above.		+ 29'3	+ 4'0	16'9	—	23'0	

In the case of Series I the chemical composition of the cupola charge was known.

In the case of Series II the physical characters of the irons in charge were known.

In the case of Series I the physical characters of the preceding day's test bars were accurately known and the same compared with daily tests for many years. By occasional analysis of test bars and some tabulations and experience, the daily small variations are translated into chemical changes which are to be applied by slight frequent adjustments to the charge by calculation from analysis of the material at hand. A greater range of material and more changes in the constitution of the charge are allowable than in case of Series II made in the old way.

tests of the cast metal. Thus the founder's skill is not wasted on uncertain material, and he becomes interested in more exact cupola practice and careful sorting and sampling of unpromising material.

That the general principles governing the deduction of quality from the ultimate analysis of cast iron were already appreciated, and to some extent applied by the writer in 1889, is evidenced by his contribution to the subject of Car Wheel Iron, under Query No. 5, *Journal of U. S. Association of Charcoal Iron Workers*, Vol. 8, No. 3, March, 1889, from which the following quotation is appropriate: "There are, therefore, probably several proper compositions for wheel mixture, each of which depends for its physical success upon the manner of working the iron as to fuel, blast, temperature, etc., and on the relative proportion of one element to another, as well as on the actual amount of each present."

The economy and success of a proper chemical system of control of mixtures is well proven, as it has been checked by daily noting of regular physical tests for transverse strength, resilience, shrinkage and chill in the case of hard iron, and occasional similar tests of soft mixtures with tensile tests in certain cases, and constant calculation of cost. Since January 1, 1892, five regular mixtures, besides frequent special mixtures (the latter often made up at short notice), requirements in fact of a foundry melting 12,000 to 15,000 tons of iron yearly, mainly for car wheels, have been met by this system with far greater certainty, uniformity and economy than ever previously by the old method of experienced estimation of physical characters of a limited and expensive range of material. The comparison of the two series of tests I and II, as given below, is probably about as favorable as can be made for the best modern practice in the old way of making and controlling iron mixtures. Series II may be taken also as representing a quality of metal about equivalent to that attained at A. Whitney & Sons' before the adoption of the above-mentioned chemical system.

Series I represents about an average specimen of A. Whitney & Sons' wheel mixture. Its physical characters

were attained by properly calculating the ultimate chemical compositions for cupola charges, and maintained without regular analyses of the casting by translating the small daily variations in physical test pieces and castings into chemical equivalents, indicating the chemical change to be made on the charge. Thus, in spite of the usual cupola return of scrap and other adverse conditions, the charges are regulated to produce practically equivalent castings. Series I was cast of same metal as our regular test bars of March 19, 1896, with no thought of comparison with another founder's metal, but merely to experiment further on the relations of chill and stress. These bars were not broken until August 20, 1896, and though the strength was not above the average, it then occurred to the writer to ask another wheel maker, expert in the old way of regulating mixtures, to contribute to the experiment. The object was to prove the same phenomena in metal cast in the same manner, in same moulds, under other conditions of mixture and cupola practice, but well within the range of good wheel metal. The request was kindly granted, the results appearing as Series II. The results of Series I were examined by the maker of Series II after his bars were cast, but before they were shipped to the writer. They were cast about September 20, 1896, packed in sawdust to prevent any "rumbling" or "molecular annealing" effect in transit, and broken by the writer in October, 1896, on the same machine and in the same manner as employed in case of Series I.

Of course, an accurate comparison of the relative merits of the old and new way of making up cast iron mixtures can only be arrived at by taking other tests and expense into account for a year or more. That comparison has been made at our works, and shows for itself on our records with an enormous balance, both physically and economically, in favor of the new way. This improvement has been more marked since January, 1893, when the business passed entirely under the control of interests having full faith in this method.

In March, 1891, daily tests of the transverse strength of the chilled wheel metal were adopted. The bars were cast

2 inches square by 15 inches long and were chilled on the four sides (*Fig. 4*). They, therefore, presented the same appearance in the cross-section as the small ingots, 1 inch square by 4 inches long, devised by Mr. Outerbridge, and illustrated by him in an abstract of his lecture on pig iron at the Franklin Institute, February 6, 1888 (*Fig. 7*).

That is, the meeting of the crystals, or lines of chill, form a more or less distinct pair of diagonals. The transverse tests of the large bars, as shown by the steady stress of the testing machine, was nearly as erratic as had been the tests of the small ingots by hammer blows, and were of use only in connection with the gray-bar tests of same metal.

In high-chilling iron particularly, the square bar of 4 square inches sectional area, cast in sand, was found very unreliable as an aid to the development of my chemical method of iron-mixing. Therefore, in January, 1895, I obviated the trouble with hard corners by making them more obtuse and adopted a hexagon cross-section of 4 square inches area (*Fig. 1*). This gives a side of 1·24 inches width to rest on knife edges.

This bar is very satisfactory for a great range of metal, and the large amount of study and tabulation above referred to has been based upon it. I was thus encouraged to make the chilled bar more reliable, and by March, 1895, after several experiments, devised the present very satisfactory form, the results of which are worth tabulating along with those of the hexagon gray bar of same metal. By keeping the same area of cross-section as before (4 square inches), but obtained by the depth $1\frac{1}{2}$ inches and width $2\frac{2}{3}$ inches (2·67 inches), a solid white bar results even with comparatively low-chilling iron. The wide sides of this bar only being cast against a chiller, while the edges or narrow sides are in contact with sand, the lines or crystals of chill form straight parallel lines, and meet end to end from opposite sides, and the meeting line being at the neutral axis of the test bar, a slight flaw or incompleteness of chill there only slightly affects the strength. In both bars contraction is measured from small lugs, whose faces are cast against a yoke of 12-inch span—one of these lugs shows in *Fig. 3*.

All bars are cast on end, and the gray bars are gated at the bottom.

No change was made in the form of chill tests, which are $2\frac{1}{2}$ inches x $1\frac{1}{2}$ inches x 6 inches, the narrow edge, $1\frac{1}{2}$ inches x 6 inches, being exposed to the iron chiller. *Fig. 2* shows the average chill test of such wheel metal as otherwise shown in *Figs. 1, 3, 4, 5, 6* and *8*.

The fracture of these probably shows a slightly higher chill than the same iron cast in the slightly different form of chill tests referred to in Series II.

Contraction is measured from small lugs cast on a corner of hexagon gray bar and on the narrow side of the rectangular chilled bar. The outer faces of these lugs are smooth, as they are cast against a cast-iron yoke protected otherwise by sand from the heat of the metal.

The $1\frac{1}{2}$-inch square bars were cast in same moulds as the regular flat-chilled bars, but from a $1\frac{1}{2}$-inch square pattern, in order to show the difference in strength of the two positions, merely by comparison of the breaking stress. For rough comparison this does very well, as when strained across the chill they break at 4,000 to 6,000 pounds, while duplicates broken by a stress in the direction of chill crystals require 9,000 to 11,000 pounds. If the regular flat bar were broken by placing it edgeways, it would not stand over 16,000 pounds, even in the case of a metal like No. 3, which, broken flat in the strong position of chill, required 17,700 pounds. If the strength were the same in the other direction, 30,100 pounds would be required to break it. Our testing machine not conveniently taking bars of this depth, $2\frac{2}{3}$ inches, the small square bars were more convenient.

Some rather imperfect tests of the crushing strength of such chilled iron show 150,000 to over 200,000 pounds per square inch in what I presume is the weak way. I know of no tests made on the ends of the crystals such as the position of load on tread of a wheel. I believe it is much over 200,000 pounds, probably 300,000 pounds at least per square inch.

Tensile strength tests in the weak way agree with a rough calculation from the transverse strength in the weak

way, being 13,000 to 18,000 pounds per square inch. In the strong way the tensile strength is probably not less than 25,000 pounds.

Note the value of watching the resilience to compare irons of the same strength for a steady load.

The wide differences here shown in strength and resilience between duplicates or similar bars of chilled iron practically equivalent though not necessarily alike in composition, broken in one case by a stress at right angles to lines of chill, and in the other by a stress in same direction as lines of chill, are therefore mainly, if not wholly, due to the relative directions of stress and chill. It will be more accurate to understand the word "chill" in the caption of this paper as meaning "the direction of the most rapid dissipation of heat." The physical effect depending upon the composition as well as upon the rapidity of the dissipation, the result is not always totally white iron.

It is to be hoped that the presentation of these facts will lead to further investigation of the subject, as the matter has a bearing upon the selection of proper forms and sizes of test bars.

The transverse strength is represented in this table by Modulus of Rupture, as by that means bars of different dimensions can best be compared.

For any bar of rectangular cross section the formula is

$$\frac{3}{2} \times \frac{Wl}{b\,d^2} = \text{modulus of rupture.}$$

Here W is stress; l, length; b, breadth; and d, depth, of test bar. By dividing the modulus in each case by 18 (the factor for a 1-inch square bar 1 foot long), the strength of such bar is shown, assuming, of course, the same grain and density as that from which the modulus was calculated. Note how reasonably close the agreement is in spite of the variations from 1 inch square to $2\frac{2}{3}$ inches x $1\frac{1}{2}$ inches in size cast. In less homogeneous metal, and particularly in gray iron, the agreement is, of course, far less close in modulus calculated from different sizes.

Some of these bars were "rumbled" to see whether in

such hard white castings any change in strength would result. In one former case of two $1\frac{1}{2}$-inch bars, which were not cast under the writer's immediate supervision, nor measured, though cast approximately $1\frac{1}{2}$ inches square like those in these series, the rumbling apparently caused 48 per cent. gain in strength, both being reported as broken in the strong position. This case was reported by the writer to Mr. Outerbridge, of Wm. Sellers & Co., in July, 1896, as showing an increase of strength by rumbling even in such iron; but evidently there is an error in that case, as no decided effect is shown in either of the present series.

Mr. Outerbridge has demonstrated the gain made by rumbling in the strength of gray iron bars, and my few experiments agree with his in general. But this uniform white iron is apparently little affected, if at all. It is also the fact that certain strong very homogeneous gray compositions gain less in rumbling than ordinary mixtures similarly cast. But further tests on this point are needed in chilled iron.

Another point of interest is the fact, that it is proven possible to cast a high-chilling iron in such form as to have nearly or quite the same modulus of rupture, whether cast in sand so as to be totally gray, or cast of the same volume between "chills" or iron sides of mould, giving a test bar of a less depth, so as to be totally white. Compare bars No. 3 (Series I) and No. 3 hexagon (*Figs. 3* and *1*). This comparison agrees with our regular tests of wheel metal since the writer devised a proper cross section and method of casting test bars for hard iron.

NOTE IN REGARD TO ILLUSTRATIONS.—The differences in shade of the various white iron sections is rather greater than natural because of the difficulty of photographing such surfaces to bring out detail. The slightly oxidized surface of No. 4 allows the detail to be reproduced with accuracy. The minute white spots in No. 10 are the brilliant reflections from graphitic scales, not from white iron. This is noted in the description of plate.

CHEMICAL SECTION.

Stated Meeting, held January 19, 1897.

DR. JOS. W. RICHARDS, President, in the chair.

THE WETHERILL MAGNETIC CONCENTRATING PROCESS.

BY H. B. C. NITZE, E.M.

This process was first described by Mr. H. A. J. Wilkens and myself, in a paper entitled "The Magnetic Separation of Non-magnetic Material," presented at the Pittsburgh meeting of the American Institute of Mining Engineers, in February, 1896, and since then published in the *Transactions* of that society. Those who may be more especially interested are referred to the above paper, as it has dealt with the subject somewhat more exhaustively than it is practicable to do here.

It is a process for separating various mineral and chemical substances, of such feeble magnetic permeability, that they have been heretofore generally considered as non-magnetic, from one another and from such accompaniments as are absolutely inert, by means of powerful and specially devised electro-magnets.

The substances that have been found capable of being so attracted are most all of the minerals containing iron and manganese, either alone or in combination; and, likewise, the chemical salts of these metals, either alone or in combination.

Among the minerals are: hematite, limonite, siderite, chromite, menaccanite, rutile, franklinite, pyrolusite, psilomelane, tephroite, rhodonite, garnet, hornblende and many others.

None of these minerals or salts is attracted (in the ordinary sense of being lifted) by the strongest hand magnet or by electro-magnets of equivalent power.

The metals iron, nickel, cobalt, and the minerals magnetite (Fe_3O_4) and pyrrhotite (Fe_7S_8) are the only substances that are magnetic in this ordinary sense, and the only ones which are capable of being separated by the various electro-magnetic machines that have been invented prior to the Wetherill machines, such as the Edison, Wenström, Ball and Norton, Conkling, Buchanan, Payne, Chase and other magnetic separators.

It is true that separations have been made of such minerals as red hematite, limonite, siderite and franklinite on some of the above types of machines, but it has invariably been accomplished only after a preliminary conversion of the iron component to its magnetic oxide or artificial magnetite, by means of roasting in an oxidizing or reducing atmosphere.

However, while these minerals and salts are not attracted by the ordinary magnetic powers sufficiently to render their separation possible, it has, nevertheless, been long known in the science of physics that all matter is affected in some way by a magnet.

Coulomb was the first physicist to announce that not only iron, nickel and cobalt, or certain mixtures of these metals with others, were influenced by a magnet, but also that small needles of all other substances, metallic, mineral or vegetable, oscillated under the influence of strong bar-magnets, like small magnetic needles. He, however, erroneously interpreted that this action was due to the universal presence of iron, in quantities so small as to defy detection by the most refined chemical analysis, and did, therefore, not consider that it was a general property of matter in itself to be magnetic.

Nearly twenty years later, in 1824, Becquerel, who had the advantage of utilizing electro-magnets, invented, since Coulomb's time, by Oersted, discovered the repulsion produced by the poles of a magnet on bismuth.

In 1846, Faraday published the results of his very interesting and exhaustive experiments, carried on with the most delicately arranged physical apparatus, showing that all matter, solid, liquid and gaseous, was magnetic; *i. e.*, either

attracted or repelled by the poles of a magnet. He accordingly made the division into paramagnetic and diamagnetic substances, the former including those attracted, and the latter, constituting by far the greater class, those repelled. He gave the following lists:

Paramagnetics.—Iron, nickel, cobalt, manganese, chromium, cerium, titanium, palladium, platinum, osmium.

Diamagnetics.—Bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold. arsenic, uranium, rhodium, iridium, tungsten.

Uranium was later found to be paramagnetic (by Verdet); and almost all amorphous and organic substances belong to the diamagnetic class.

The paramagnetic substances may again be subdivided into such as are highly magnetic and such as are only feebly so.

The first class is completed with the substances iron, nickel, cobalt, magnetite and pyrrhotite. It is with the second class that we are especially concerned here.

The knowledge of the paramagnetic property of many substances has been of great scientific interest since the time of Faraday's demonstration.

In 1871, Fouqué, and since then Doelter and other mineralogists, have made use of this knowledge to some extent in the mineralogical laboratory.

But it remained for Mr. J. Price Wetherill, of South Bethlehem, Pa., to design magnets capable of producing a sufficiently concentrated field to make practical the separation of these feebly paramagnetic substances on a commercial scale. Mr. Wetherill, who is the general manager of the Lehigh Zinc and Iron Company, was led to this result in his endeavor to improve the grade of the zinc ore of Sussex County, N. J., used for the manufacture of spelter.

This ore is a crystalline granular aggregate of franklinite (FeO, ZnO, MnO) (Fe_3O_4, Mn_3O_4), willemite (Zn_2O, SiO_2) and calcite, with smaller amounts of zincite (ZnO), fowlerite (MnO, ZnO, SiO_2), tephroite (Mn_2O, SiO_2), and garnet.

It was the object to obtain the zinc-bearing minerals willemite and zincite as free as possible from the franklin-

ite, garnet, tephroite and fowlerite, the iron- and manganese-bearing minerals, as the presence of the latter is fatal to the direct metallurgical production of zinc.

After repeated and painstaking experiments, Mr. Wetherill finally succeeded, in the latter part of 1895, in accomplishing this result to perfect satisfaction, and patents have since been granted in the United States, Canada, England,

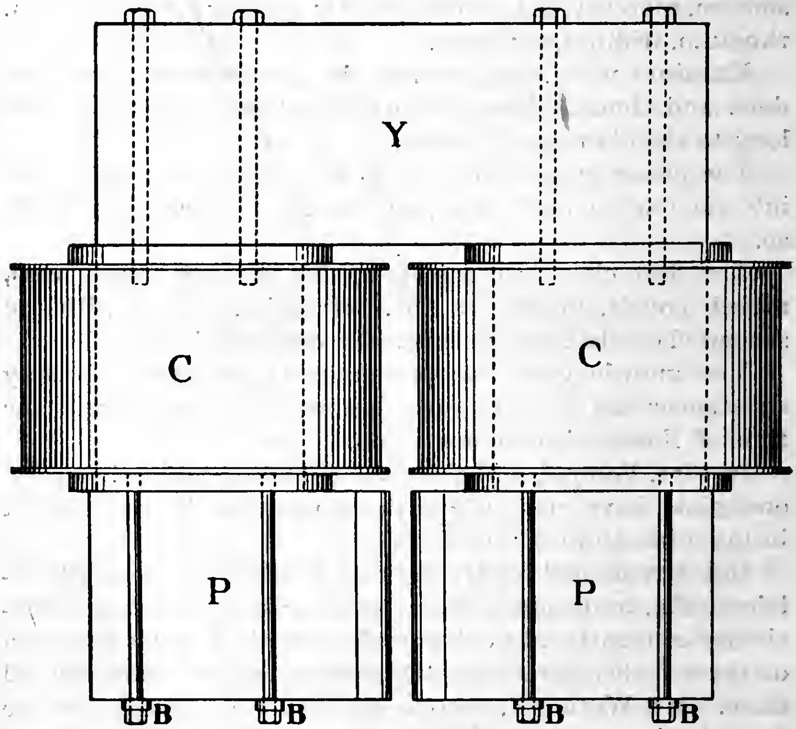


FIG. 1.—Plan of Wetherill electro-magnet.

Germany and other European countries, for the method of, and apparatus for, separating paramagnetic substances of very low magnetic permeability or susceptibility.

The accompanying illustrations show the form and arrangement of the magnets, as well as the principal features of the mechanisms for effecting the separation of substances subjected to their influence.

The electro-magnets are arranged in the general form of a horseshoe, as shown in plan (*Fig. 1*), and consist of five parts, made of soft forged iron; two cores and bobbins *C*, joined together by a yoke *Y*, and having attached to each of their other faces, by means of brass clamps *B*, a pole-piece *P*, as shown. The yoke is 31¼ inches long by 10¾ inches wide by 2½ inches thick. The cores are 12½ inches long by 10¾ inches wide by 2⅝ inches thick, made rectangular in cross-section, with the long edges rounded to a radius of one-half the thickness. These cores are wrapped with nineteen layers of No. 5 insulated copper wire, making 915 ampère-turns. The pole-pieces are 15½ inches long by 10¾ inches wide by 2½ inches thick, and are tapered at the free ends at

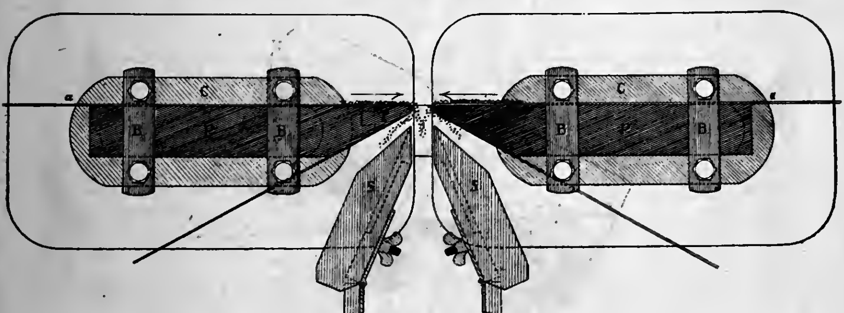


FIG. 2.—Vertical view of horizontal magnet type.

an angle of 30°, the points being rounded. The total weight of this magnet complete is 1,259 pounds.

The mechanisms for effecting the separation of minerals are of two principal types, as shown in the drawings, representing vertical views (*Figs. II* and *III*).

(1) The horizontal magnet type (*Fig. II*) in which the material is fed by means of hoppers, in a thin layer on canvas belts *a*, revolving in the directions shown by the arrows about each pole-piece *P*, and is delivered directly into the opening between the two pointed pole-pieces. Two shutters *S*, made of brass and of the same width as the pole-pieces, are situated one beneath the point *T* of each pole; they are adjustable so that the magnetic particles, which adhere slightly to the belts as they round the pole-points,

are carried to one side by the moving belts, while the non-magnetic particles fall vertically in the central space between the two shutters.

The result desired can be regulated by changing the position of the shutters, the speed of the feed belts, the distance between the pole-points, or the ampèrage of the electric current through the coils.

(2) The inclined magnet type (*Fig. III*) in which the material enters on the feed belt *a*, revolving about a brass roller *R*, and is delivered in close proximity to the space between the poles. The magnetic particles are withdrawn and lifted up into the highly intensified field existing at this point, and they are removed by the horizontal belt *b*, revolv-

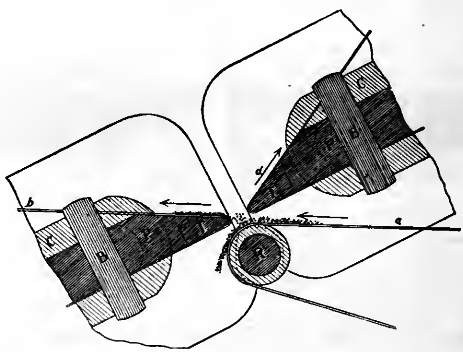
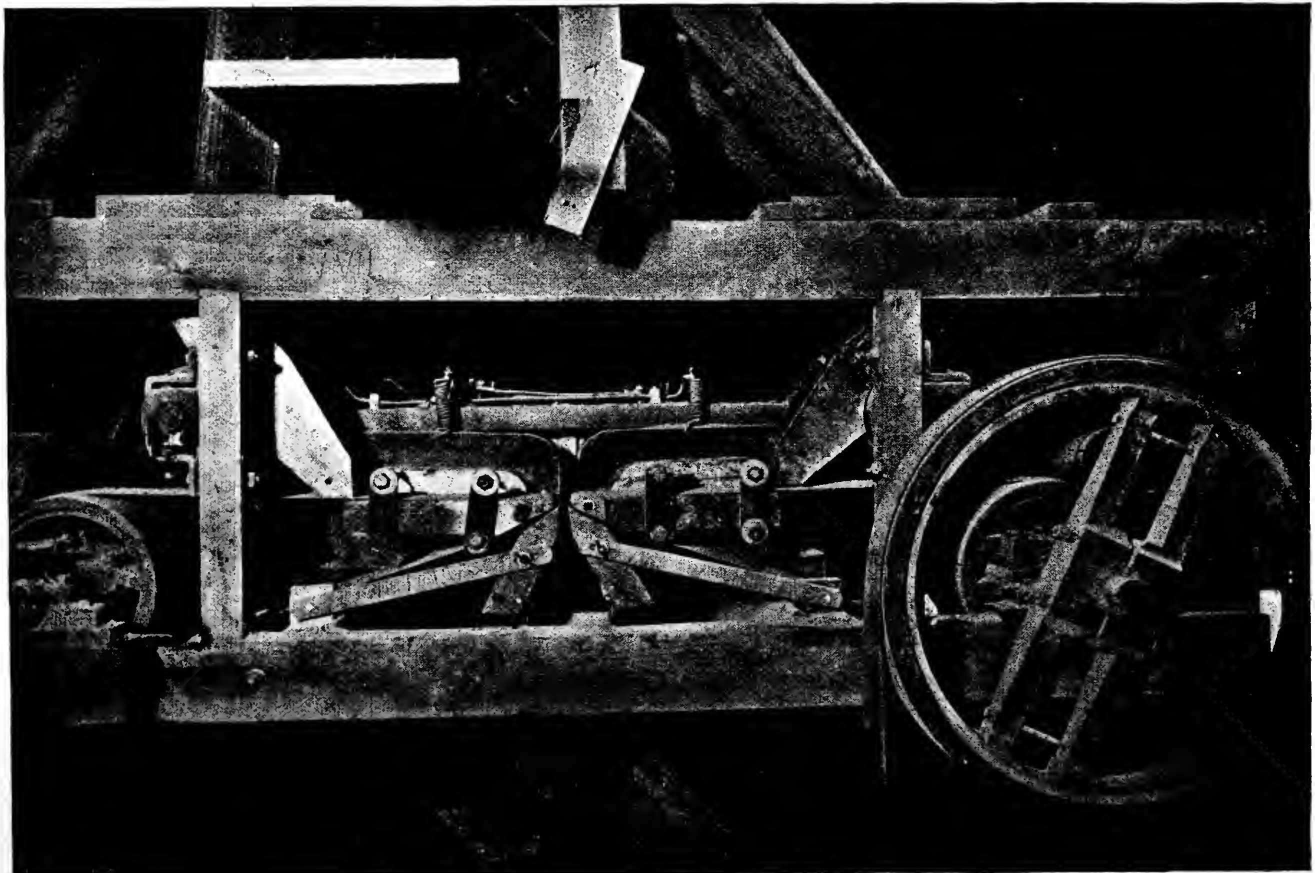


FIG. 3.—Vertical view of inclined magnet type.

ing around the lower pole point in the same direction as the feed belt; while the non-magnetic particles fall vertically from the brass roller. The revolving belt *d* around the upper pole simply serves the purpose of keeping that point brushed free from magnetic particles that would otherwise have a tendency to stick to the bare points, and ultimately choke the opening.

The intensity of the magnetic attraction can be accurately adjusted by changing the distance between the poles, the distance of the brass roller from the poles, or the ampèrage of the electric current.

The question of paramount interest is: How are these magnets capable of effecting a separation that has not been



Flat Magnet Concentrating Machine in the Plant of the Sterling Iron and Zinc Company, at Franklin Furnace, New Jersey

practicable heretofore? How is it that substances possessing such infinitesimal magnetic permeability, that they have been commonly considered as non-magnetic, are attracted here, and actually lifted by the poles of the magnets?

The answer lies in the extremely condensed magnetic field at the pole-points, which is produced by means of the correctly proportioned cores, yokes and pole-pieces employed, and especially by the tapering ends of the latter. These ends being of less sectional area than the magnet cores, a vast number of magnetic lines are forced through and across the points.

The amount of ampèrage necessary to generate these lines in sufficient number is comparatively small. The magnetizing power of a magnet may be attained either by increasing the ampèrage of the current, or by increasing the ampère-turns, *i. e.*, the number of turns of the coil on the core, the one or the other of these functions remaining constant.

In the Wetherill magnets the latter fact is taken advantage of, and with 915 ampère-turns of No. 5 wire the quantity of current or ampèrage is reduced to an economic minimum.

The No. 5 wire is capable of carrying a current of 25 ampères, but this quantity is rarely necessary for most minerals.

For instance, limonite and pyrolusite, which are perhaps among the most stubborn of the feebly magnetic minerals, require from 10 to 20 ampères; red hematite and garnet are usually attracted with from 4 to 8 ampères; and franklinite and siderite with as low as 1 to 4 ampères.

The amount of voltage is an inconsequent factor, depending solely on the size and length of wire and the number of ampères used; *i.e.*, it represents the pressure requisite to drive the necessary ampèrage through the magnets. For coils wrapped with No. 5 wire the voltage is equal to about twice the number of ampères used; *i. e.*, the resistance is 2 ohms; for coils wrapped with No. 10 wire the resistance is 5 ohms.

To illustrate the intensity of the magnetic field it may

be mentioned that the current of a single bluestone cell (such as is used in telegraphy) is usually too powerful to permit of a satisfactory separation of the highly magnetic substances magnetite or pyrrhotite, the particles adhering to the points so tenaciously that the moving belts are incapable of pulling them off. For this purpose it is found best to reduce the strength of the current by means of resistance coils.

The ability to delicately adjust the magnetic intensity of the field permits, in many cases, the successive isolation of several products, showing a slight difference in permeability from a mixture containing the same. For instance, in the New Jersey zinc ore, franklinite can first be separated at 1 to 3 ampères, and then the garnet at 4 to 8 ampères.

This brings up the interesting question of the possibility to tabulate the minerals in distinct groups capable of being magnetically separated from one another, *i. e.*, in the order of their relative attractability. It is, however, a matter of very considerable difficulty to do this accurately, for the reason that the magnetic permeability of each mineral, in itself, is subject to wide variations; for instance, some particles of franklinite will be attracted at 1 ampère, while others will require as high as 4 ampères; some garnets will be lifted at 3 ampères, and others not until 6, 7 or 8 ampères are reached.

Nevertheless, various attempts have been made in the past by physical investigators, with more or less success and reliability of results, to determine the magnetic permeability of substances, and it may be of interest to give some of their determinations.

Delesse (*Annales des Mines*, IV Ser., Vol. XIV, p. 429) gives, among many others, the following comparative values, taking the magnetic attractability of steel at 100,000.

Magnetite	65,000
Siderite	120
Hematite	93 to 43
Limonite	72 to 43

Plücker (*Pogg. Annalen*, Vol. LXXIV, 1848) gives, taking metallic iron at 100,000:

Magnetite	40,227
Red hematite	134
Hydrated ferric oxide	156
Proto-sulphate (vitriol) of iron	98
Pyrite	150
Hydrated Mn_2O_3	70
Mn_3O_4	167

These results verify one important point, namely, the undoubted existence of a wide gap between the strongly and the weakly magnetic substances, according to which the paramagnetics are divided into two classes, as mentioned in the beginning of this paper.

The accuracy and value of the figures, otherwise, is extremely doubtful, and in some instances they are known to be absolutely erroneous and misleading, so far as experience with the Wetherill magnets goes. A striking instance of discrepancy is furnished by pyrite and iron vitriol, the former of which Plücker rates at 150, and the latter at 98. Yet the fact is that iron vitriol is attracted with ease at 8 ampères, while iron pyrites is the only iron-bearing mineral that does not, so far as present experiments have gone, come within the attracting limit of the magnets at all, although it is still hoped that it will be possible to further increase the intensity of the field by which it will be made effective upon a wider range of minerals than has been successfully treated so far, including iron pyrites.

Again, whereas Plücker places the permeability of the manganese salts not far from, and even below that of pyrite, their attractability is, in reality, far greater. It is, indeed, a curious and interesting fact that the manganese salts are, as a rule, more magnetic than the corresponding iron salts; for instance manganous sulphate (c. p.) requires only 1 ampère, while ferrous sulphate (c. p.) requires 8 ampères to be attracted.

It does not appear then that the magnetic permeability necessarily depends upon the amount of iron in a substance, or upon the chemical condition of that iron in a ferrous state, as has been thought by many. But how is this property of matter best explained?

Without here desiring to enter into a discussion of the

theories concerning the magnetic properties of matter, it may be stated briefly that, in view of existing facts, the magnetic molecular theory seems the most satisfactory to us. This theory accounts for the magnetism of bodies by the existence of magnetic molecules and explains the variation of permeability as due to the arrangement and structure of these molecules.

The ratio of the sum of the volumes of the magnetic molecules to the entire volume of a body is the magnetic density of that body. It is upon this that the capacity of a body for magnetism seems to depend, and it has been shown to vary with the temperature and other physical and chemical conditions.

In conclusion, I will give some actual results obtained in concentrating different ores by the Wetherill process:

ZINC ORES.

From Franklin, N. J.

	Percentage by Weight.	ZnO Per Cent.	Fe Per Cent.	Mn Per Cent.
Original ore	—	31·09	20·34	9·34
Franklinite, garnet, etc. (magnetic heads)	56	24·38	35·50	13·62
Willemite and zincite (non-magnetic tails)	28	60·00	1·50	6·10
Calcite (non-magnetic tails)	16	4·00	—	—

From Austinville, Wythe County, Va.

	Percentage by Weight.	Fe Per Cent.	Zn Per Cent.
Original ore	—	18·60	29·57
Limonite (magnetic heads)	33	49·45	5·58
Calamine (non-magnetic tails)	67	3·41	41·40

RED HEMATITE IRON ORES.

(From the Birmingham district, Alabama.)

	Percentage by Weight.	SiO_2 Per Cent.	Fe Per Cent.
Original	—	27·14	45·32
Magnetic heads	49	12·29	56·47
Non-magnetic tails	51	41·41	34·60

(From the Pewabic Mine, Michigan.)

	Percentage by Weight.	SiO_2 Per Cent.	Fe Per Cent.
Original	—	43·49	37·87
Magnetic heads	37	7·76	63·55
Non-magnetic tails	63	64·11	23·05

BROWN HEMATITE ORE.

(From Iron Gate, Va.)

	Percentage by Weight.	SiO_2 Per Cent.	Fe Per Cent.
Original	—	31·29	43·98
Magnetic heads	63	11·24	51·04
Non-magnetic tails	37	66·00	31·74

SILVER-LEAD ORE.

(From Monterey, Mex., consisting of galena in a limonite gangue.)

	Percentage by Weight.	Ag, ozs. Per Ton.	Pb Per Cent.	Fe Per Cent.	SiO_2 Per Cent.
Original ore	—	6·41	12·04	35·42	12·68
Magnetic heads	81	0·90	2·90	43·00	14·10
Non-magnetic tails	19	29·90	51·00	3·10	6·60

MANGANESE ORE.

(From Cave Spring, Ga.)

	Percentage by Weight.	SiO_2 Per Cent.	Mn Per Cent.
Original	—	43·00	28·78
Magnetic heads	52	20·85	40·91
Non-magnetic tails	48	67·20	15·54

Among the materials, besides those mentioned above, which have been separated successfully, are:

(1) A mixture of apatite and rutile, occurring in a deposit near Charlottesville, Va.

(2) Monazite sand from North and South Carolina, from which rutile and garnet were completely removed.

(3) Garnetiferous rocks and schists, from which it was desired to obtain the pure garnet.

(4) Garnetiferous copper ore from Mexico.

(5) Corundum ores, from which garnet and other deleterious ferruginous minerals were to be removed.

(6) Ores containing siderite, as in cryolite from Greenland, and the foreign zinc-blende ores.

DISCUSSION.

PROF. F. LYNWOOD GARRISON:—For the past three or four years a magnetic process for the concentration of copper and zinc ores (sulphides) has been in operation at Pitkäranta, Finland.

The ores used for this purpose are so lean, and mixed with so large a proportion of worthless material, that they cannot be worked by the ordinary methods of concentration and smelting. They are essentially mixtures of pyrite, chalcopyrite and zinc-blende, often associated with magnetite.

This lean copper ore, which, under ordinary circumstances, would be thrown away, containing about 1 per cent. copper, is crushed by ordinary Blake crushers and then granulated by rolls to a size of about 0·75 millimeters.

It then passes into roasting furnaces. The ore is thus gently roasted, which is a delicate operation, as the temperature must be very carefully regulated. The copper ores appear to require a lower temperature for roasting than the zinc ores, in order to render them magnetic; more or less difficulty has been experienced with the zinc-blende in this respect. When the ore comes from the furnace it is red-hot and glowing; when cold, it is passed by mechanical means to the magnetic separators, which are constructed with the special view of concentrating such magnetic material.

It is claimed that in this way from 70 to 80 per cent. of the copper in the ore is separated out, the refuse containing only about 0·20 per cent. copper. At Pitkäranta, about 600 hundred-weight of ore is treated in twenty-four hours, or about 1 ton per hour.

The results obtained with the concentration of zinc ores have not been so satisfactory, and the work on them is still in an experimental stage. The difficulty appears to be in the roasting, the proper conditions for which do not seem to be entirely, as yet, understood.

Mr. Nitze:—Prof. Garrison's description of the magnetic concentrating process as applied to copper and zinc ores containing pyrite, at Pitkäranta, Finland, is very interesting, and corroborates the fact which I brought out in the beginning of my paper, namely, that apparently non-magnetic minerals have been separated on magnetic machines of the ordinary types, but only after a preliminary roasting of the material in order to render it artificially magnetic. It appears from the description that the roasting at Pitkäranta is carried on in a simple oxidizing atmosphere. No mention is made of the addition of coal, carbon, or a reducing gas to the charge. Therefore, the idea aimed at is evidently the conversion of the pyrite into pyrrhotite (the magnetic iron sulphide), by driving off a portion of its sulphur; the roasting must be arrested just at the point where the correct amount of sulphur has been eliminated, and it is for this reason that the operation becomes a most delicate one. If it be carried beyond this point the material will again become non-magnetic to the ordinary magnets. At the best, the uniformity of magnetization of the roasted product must be imperfect.

It must also be considered that, naturally, a partial concentration of the copper in the ore is effected by the roasting operation alone, the weight of the total mass being reduced by the amount of sulphur driven off.

Regarding the conversion of pyrite into pyrrhotite, it may be mentioned that Eustis and Howe (*Trans. Amer. Inst. Mining Engineers*, Vol. X, p. 105) in 1882 suggested the reduction of iron and nickeliferous pyrite to the magnetic subsulphide, but the delicacy of the operation deterred its practical application.

Mr. G. G. Convers, superintendent of the Lehigh Zinc and Iron Company, South Bethlehem, Pa., in (about) 1893, made similar experiments on magnetizing the pyrite con-

tained in a mixture of blende, pyrite and gangue from the Arminius Pyrite Mine, Louisa County, Va. He roasted the material to just the exact point to make pyrrhotite, but he found the operation such an extremely delicate one that he concluded it could not be carried out on a practical scale.

Besides the above, there are others who have experimented in the same direction and with similar results, apparently demonstrating the impracticability of such a delicate roasting operation; and it seems, therefore, the more remarkable that it should be practically successful at Pitkäranta.

However, if the roasting be carried still further, so as to drive off all of the sulphur (dead roast), converting the pyrite into Fe_2O_3, and the operation be completed in the presence of a reducing atmosphere, such as can be attained by the admixture of carbon in the charge, so as to reduce a portion of the Fe_2O_3 to FeO, the ferruginous material will then be in the condition of artificial magnetite (Fe_3O_4), which can be separated on the usual types of magnetic machines.

The great objection to such a magnetizing roasting, aside from the additional cost of the same, is that it is never perfect; the probabilities are that there will always be some particles which have not become magnetized, and will therefore pass into the tails in the process of concentration.

This disadvantage is eliminated in the Wetherill process, where any previous *magnetizing* roasting becomes not only superfluous, but undesirable, inasmuch as the magnetic permeability of Fe_2O_3 is sufficient to cause its attraction and removal in the highly condensed field of the magnets. In pyritic ores, therefore, the only operation necessary would be a simple dead roast, which can be easily and perfectly attained.

Mr. —— (a visitor), in reply to an inquiry by Dr. Wahl, whether the fine sizes of iron ores produced in concentration could be utilized in the furnace, said that this difficulty had been well overcome, as was demonstrated by the successful and practical use of such fine ores in the blast furnaces of the Lackawanna Iron and Steel Company, at Scranton, Pa.;

Stated Meeting, February 16, 1897.

SOIL FERMENTS IMPORTANT IN AGRICULTURE.*

By Harvey W. Wiley,
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Introductory.—Soil ferments important in agriculture are those which help to make the soil from original rocks and those which are active in preparing the food of plants for absorption and assimilation. The old idea that the soil is an inert mass of mineral matter has given way to the new conception of the soil as a living organism. The parts of the soil which are not endowed with life at the present time have their highest significance as the environment of the living organisms which they contain, and which they may help to nourish. The plant which forms the growing crop receives its nourishment through the media of the air and soil, but this nourishment must undergo a process of digestion, similar to that suffered by the food which nourishes animals, before it becomes available as plant food. Indeed, the purely mineral, inorganic foods of plants are probably not always absorbed as such, and must undergo a decomposition before they are assimilated. A striking instance of this is shown in the case of silica, an important plant food and a type of inert mineral matter. Silica is highly insoluble and apparently the least suited of the mineral constituents of the earth to enter the vital organism of the plant. Yet not only do we find it in the tissues of the mature plant, but also, strange to say, in the greatest abundance in those parts of the plant organism—viz.: the leaves—most remote from the sources of supply. It is evident from this that the highly insoluble silica of the soil must undergo a

* Abstract of a lecture delivered before the Chemical Section of the Franklin Institute, February 16, 1897.

complete solution in order to be carried by the juices of the plant through the network of cellular tissues, to be finally redeposited in the leaf.

The part which soil ferments have played in the formation of arable soil from the original rocks is not thoroughly appreciated. The naked rocks of high mountains comprise mineralogical types of the most varied nature, viz.: granite, porphyry, gneiss, mica schist, volcanic rocks and limestones of all varieties, and all these have been found to be covered with a nitrifying ferment which is doubtless extremely active in producing incipient decay. At the high altitudes in which these observations have been made, the activity of bacteria is necessarily limited by the low temperature to which they are subjected during the greater part of the year. During the winter season their life is suspended, but is not extinguished, since they have been found living and ready to resume all their activity after an indefinite sleep, perhaps of thousands of years, on the ice of the glaciers, where the temperature never rises above the freezing point. When the activity of these ferments in the most unfavorable conditions is recognized, it is easily seen how much more active they become when brought down to lower levels, where they are nourished by the favoring conditions which exist, especially during the summer, in cultivated soils. In fact, the importance of the action of these bodies on the mineral particles of which the soil is largely composed has never been fully recognized, and there is no doubt whatever of the great significance of their decomposing action in the liberation of plant food locked up in undecomposed mineral structures. In this case the activity of the bacteria is not limited to the surface of rock masses, but permeates every particle of soil and thus becomes effective over a vastly extended surface.

When the extreme minuteness of these organisms and of the phenomena which they produce is considered, there may be a tendency to despise their importance; but by reason of the fact that their activity is never ceasing and of the widest application, it must be placed among the geologic causes to which the crust of the earth owes a part of

its actual physiognomy, and to which the formation of the deposits of the comminuted elements constituting arable soil is due.

But the action of these ferments has not stopped with the aid they have given to soil formation. It is highly probable that they assist in a most marked manner in the final dissolution of the soil particles, and the setting free of the plant foods which they contain. It is quite certain that in the primary decay of bare rocks, especially at high altitudes, the nitrifying organism plays a highly important part, preparing the surface of the rock for the first growth of lichens and other low vegetable organisms, from which the first traces of humus are formed. The discovery that the nitrifying organism can subsist upon a purely mineral food is one of the chief supports of the idea that they were especially active in the very beginning of soil formation. It has been shown that these bacteria can be developed by absorbing from the ambient atmosphere traces of ammonia and other bodies which may be present in the air. There is thus discovered in the very first products of the attrition of rocks the characteristic element of vegetable soil, viz.: humus, the proportion of which increases rapidly with the processes of disintegration, until finally the decaying mass is capable of sustaining chlorophyll-containing plants. Not only upon the surface of exposed rocks have these organisms been discovered, but they are found to extend also to a considerable distance in the interior. They not only play an important part by direct action upon the mineral matters which the rocks contain, but later on, through the production of nitric acid, greatly favor the final solution of the soil particles.

Kinds of Organisms in the Soil.—The nitrifying organisms in the soil exist in common with hundreds of others, many of which are doubtless active upon the soil particles. The organisms to which particular attention is called in this address, in addition to those which help to dissolve the soil particles already mentioned, are those which are active in preparing organic foods for absorption and assimilation by

plants, and those which act upon free atmospheric nitrogen, and bring it into a shape suited to plant nutrition.

In general these are called the nitrifying ferments, and their action is uniformly favorable to vegetable growth. Attention should also be given to another class of organisms found in the soil, whose activity is inimical to plant growth or hurtful in some other way. This class comprises the denitrifying organisms, and those of a pathogenic nature which may exist in the soil, and by their activity cause disease in man and beast.

The Nitrifying Ferments.—The micro-organisms of most importance to agriculture, and those to which attention is particularly called in this article, are the bacteria which act upon nitrogenous matters and oxidize them to nitric acid, or which exert a reducing effect on nitric acid, bringing it to lower forms of oxidation, or even to free nitrogen. These organisms belong to many different species, and act in very many different ways. The general group to which they belong is known as nitro-bacteria. The classification of these organisms by genera and species would prove of little interest to the readers of this article. In general it may be said that there are three distinct genera, comprising, in the first place, those organisms which form ammonia or carbonate of ammonia from organic nitrogenous compounds, such as albumin; in the second place, the organisms which transform carbonate of ammonia into nitrous acid; and, in the third place, those which transform nitrous into nitric acid. Each genus is necessary in the complete transformation of proteid matter into nitric acid, in which latter form alone nitrogen is chiefly available for plant food.

Production of Ammonia.—The bacteria which are especially active in the formation of ammonia are found constantly in surface soils and in the air and rainwaters. By the activity of these organisms in the decomposition of proteid matter, large quantities of ammonium carbonate are produced. The organic carbon which is present in a compound is acted upon during the oxidation of the proteid, and carbon dioxide and certain organic acids are formed.

The organic sulphur which is present is converted into sulphuric acid, and the hydrogen partly into water and partly into ammonia. This oxidation is accomplished by bacteria, and, to a less extent, by moulds and yeasts. The table shown on the screen contains the names of the common soil bacteria, which ammonize proteid matters. The column headed "per cent." shows the amount of proteid matter changed into ammonia by the several organisms in twenty days at a temperature of 30°. Of all the bacteria which have been studied, the species mycoides has the highest ammonizing power, being capable of changing nearly half of the proteid into ammoniacal nitrogen in the time named. In soils where the environment does not permit of the development of the nitrifying ferments, the change stops with ammonia. Such conditions are found in the vegetable soils of swamps, which are extremely acid. In such soils ammonia is quite freely produced, while the nitrous and nitric organisms are absent.

In the analysis of a swamp soil, which had been shown by a bacterial culture to contain no nitrifying ferments, 0·03698 per cent. of nitrogen was found as ammonia and only a trace as nitric acid. In another vegetable soil, which contained nitrifying organisms, 0·0336 per cent. of ammoniacal and 0·0474 per cent. nitric nitrogen were present. Of the moulds, several have been found capable of producing considerable quantities of ammonia. Among these *Cephalothecium roseum* converted over 30 per cent. of proteid into ammoniacal nitrogen in five days, and *Aspergillus terricola* was only a little less active.

The yeasts are still less active, but a large number of them produces ammonia in small quantities.

In general, it may be said that in cultivated soils, which have a neutral or alkaline reaction, bacteria are almost the sole ammonia makers, while in vegetable soils of a marked acid reaction, as in swamps and forests, the moulds are the chief producers of ammonia.

In the oxidation of albumin by the *Bacillus mycoides* the carbon is oxidized to carbon dioxide, the sulphur to sulphuric acid and the hydrogen to water and to ammonia.

The reaction may be expressed by the formula

$$\underset{\text{Albumin}}{C_{72}H_{112}N_{18}SO_{22}} = \underset{\text{Water}}{29H_2O} + \underset{\text{Carbon dioxide}}{72CO_2} + \underset{\text{Sulphur trioxide}}{SO_3} + \underset{\text{Ammonia}}{18NH_3}$$

The *Bacillus mycoides*, under certain conditions, can form ammonia also from nitrates. In the absence of oxygen it reduces nitrates to ammonia in presence of an organic substance like sugar. In this action it is anærobic, while in the ordinary process of converting proteid matter into ammonia the action takes place in the absence of oxygen. This is a curious instance of a reverse action produced by the same organism in a different environment, showing, as it does, an oxidizing action in the presence of oxygen, and a reducing action in its absence. Some idea of the character of the *Bacillus mycoides* and the methods of its culture can be gained by a study of the photographs which will now be projected upon the screen.

Production of Nitrous Acid.—The next step in the process of nitrification is the conversion of ammonia or its compounds into nitrous acid. With a moderate store of ammonia the oxidation into nitrous acid takes place, as a rule, without any of the nitrogen being lost in a free state or being volatilized as ammonia compounds. When, however, there is a large excess of ammonium carbonate, a considerable loss of nitrogen may take place. The practical deduction to be drawn from this fact is apparent. Nitrogenous fertilizers should be applied only in moderate quantities, so as not to increase the stock of material beyond the power of the active ferments to handle it.

The nitrous ferment is by far the largest and most vigorous of the nitrifying organisms. It is from three to four times as large as the nitric ferment, and under a high power of the microscope appears as minute globules, slightly oblate. These globules are multiplied by fission and the divided parts develop rapidly to perfect organisms of full size. In most cases the organisms appear as distinct globules, but many are congregated into masses where the distinctive cell structure seems to be lost. A photograph of the nitrous organism is shown upon the screen.

Conversion of Nitrous into Nitric Acid.—The last step in the process of nitrification consists in the oxidation of nitrous to nitric acid. As a rule, plants absorb nitrogenous food only as nitric acid, but it cannot be said that the nitrogen may not be used by the plant in other forms. Some experiments seem to show that ammonia and its compounds and humus may be directly absorbed by plants, but if this be true it must be only in very limited quantities. The final step, therefore, in nitrification is necessary to secure this valuable food in its most highly available state. The nitrifying organisms are much smaller than their nitrous cousins, and of the same general shape, but more globular.

It must not be supposed that these steps in the preparation of a nitrogenous food are performed with entire distinctness. The impression might be obtained that the ammoniacal ferment exerted its activity, converting the whole of the nitrogenous supply into ammonia, and that in this state only the nitrous ferment would become active and convert the whole product into nitrous acid, which finally, under the influence of the nitric ferment, would form nitric acid. In point of fact, however, in arable soils and under favorable conditions, the steps of nitrification may be almost synchronous. In the case of a growing crop, a chemical examination or repeated chemical examinations might find only traces of ammonia and nitrous and nitric acids. As each particle of ammonia is formed, it is converted without delay into nitrous acid, and then at once into nitric acid. The nitric acid formed is absorbed by the growing plant, and thus it might seem that the activity of the ferments present in the soil had been reduced to a minimum, when in point of fact they were exercising their functions with maximum vigor. The separate stages of nitrification mentioned above can only be secured in the laboratory by a skilled bacteriologist patiently working to separate the different genera of nitrifying organisms until he procures them in an absolutely pure form. As may be supposed, this is very difficult to accomplish.

(A photograph of the nitric organism was shown upon the screen.)

Ferments Oxidizing Free Nitrogen.—In the preceding paragraphs the attention of the reader has been briefly called to the action of those species of ferments which attack nitrogen in some of its forms of combination. Since nitrogenous food is the most expensive form of nutriment which the plant consumes, it is a matter of grave importance to agriculture to know the full extent of the supply of this costly substance. It is evident that the continued action of nitrifying ferments finally tends to exhaust the stores of this substance which have been provided in the soil. The quantities of oxidized nitrogen produced by electric discharges in the air and by other meteorological phenomena, and which are brought to the soil in rain waters, are of considerable magnitude, but lack much of supplying the ordinary wastage to which the stores of soil nitrogen are subjected. Even with the happiest combination of circumstances, it is not difficult to see in what way the available stores of nitrogen could be diminished to a point threatening the proper sustenance of plants, and thus diminishing the necessary supplies of human food. The examination of the drainage waters which come from a fertile field in full cultivation, is sufficient to convince the most skeptical of the fact that the growing crop does not by any means absorb all of the products of the activity of the nitrifying ferments. Nitric acid and its compounds, the nitrates, are exceedingly soluble in water, and for this reason any unappropriated stores of them in the soil are easily removed by heavy downpours of rain. Happily the living vegetable organism has the property of withholding nitric acid from solution, either by some property of its tissues or more probably by some preliminary combination which the nitric acid undergoes in the plant itself. This is easily shown by a simple experiment. If fresh and still living plants be subjected to the solvent action of water, very little nitric acid will be found to pass into solution. If, however, the plants be killed before the experiment is made, by being exposed for some time in an atmosphere of chloroform, the nitric acid which they contain is easily extracted by water.

The losses, therefore, which an arable soil sustains in its

content of nitrogenous matter must be supplied either by the addition of nitrogenous fertilizers or by some action of the soil whereby the nitrogen which pervades it may be oxidized and fixed in a form suited to the nourishment of plants. The discussion in regard to the possibility of fixing nitrogen in the soil has been carried on with great vigor during the last two decades. The proof, however, is now overwhelming that such fixation does take place. It would not be proper here to enter into a discussion of the processes by which this fixation is determined, and, in fact, they are not definitely known. One thing, however, is certain, viz.: that it is accomplished by means of micro-organisms or ferments similar, perhaps, in their nature to those already mentioned, but capable of absorbing, assimilating and oxidizing free nitrogen.

Methods of Oxidizing Free Nitrogen.—At the present time, it is sufficiently well known that this operation takes place in two ways. In the first place, there are found to exist on the rootlets of certain plants, chiefly of the leguminous family, colonies of bacteria whose function is known by the effects which they produce. In such plants in a state of maturity, as was mentioned above, are found larger quantities of organic nitrogen than could possibly have been derived from the soil in which they were grown or from the fertilizers with which they were supplied. Cultural experiments in sterilized soils, with careful exclusion of all sources of organic nitrogen, have proved beyond question that this gain in nitrogen is found only in such plants as are infected by the organism mentioned. The logical conclusion is therefore inevitable that these organisms, in their symbiotic development with the plant rootlets, assimilate and oxidize the free nitrogen of the air and present it to the plant in a form suited to absorption. Attempts have been made to inoculate the rootlets of other families of plants with these organisms, but so far without any pronounced success. There are, however, certain orders of low vegetable life, such as cryptogams, for instance, which seem to share to a certain degree the faculty of the leguminous plants in acting as a host for the nitrifying organisms men-

tioned. The observation above recorded becomes a sufficient explanation of the fact that the fertility of fields is increased by the cultivation of leguminous plants, which would not be possible except they possess some such property as that which has already been described.

Another order of organisms has also been discovered which is capable of oxidizing free nitrogen when cultivated in an environment from which organic nitrogen is rigidly excluded. It seems probable, therefore, even in soils which bear crops not capable of developing nitrifying organisms on their rootlets, that the actual stores of available nitrogen may be increased. This fact explains the observation which has frequently been made that in fields which are not cultivated, but which remain in grass, there may be found an actual increase in the total amount of nitrogen which is available for plant growth. As will be seen further along, the soil is also infested with an organism which is capable of destroying nitric acid and returning the nitrogen which it contains to the air in a free state. It seems almost certain that in every complete decomposition of a nitrogenous organism a part of the nitrogen which it contains escapes in the free state. Were it not, therefore, for the fact that this free nitrogen can be again oxidized and made available for plant growth, the total stores of organic nitrogen in existence would be gradually diminished, and the time would ultimately come when their total amount would not be sufficient to sustain a plant life abundant enough to supply the food of the animal kingdom. Thus the earth itself, even without becoming too cold for the existence of the life which is now found upon it, might reach a state when plant and animal life would become practically impossible by reason of the deficit of nitrogenous foods.

Much less is known concerning the character and activity of the organisms that oxidize free nitrogen than of those which feed upon organic nitrogen. It cannot be doubted, however, that these scarcely known ferments are of the greatest importance to agriculture, and the further study of their nature and the proper methods of increasing their

activity cannot fail to result in the greatest advantage to the practical farmer. (Photographs showing the occurrence of the nitrifying tubercules of leguminous and other plants were shown upon the screen.)

Fertilizing Ferments.—Two years ago I used the following words in a report published by the Department of Agriculture:

"When a soil is practically free from albuminoid bodies and contains but little humus, the attempt to develop a more vigorous nitrifying ferment would be of little utility. Even in a soil containing a considerable degree of humus, it may be found that its nitrogen content has been so far reduced as to leave nothing practically available for the activity of nitrification. In such cases the only rational method of procedure is in the application of fertilizers containing nitrogen. In other cases where the lack of fertility is due to the extinction or attenuation of the nitrifying ferment, remunerative results may be obtained by some process of seeding similar to that described above. It is entirely within the range of possibility that there may be developed in the laboratory species of nitrifying organisms which are particularly adapted for action on different nitrogenous bodies. For instance, the organism which is found most effective in the oxidation of albuminoid matter may not be well suited to convert amides or the inert nitrogen of humus into nitric acid. We have already seen the day when the butter-maker sends to a laboratory for a ferment best suited to the ripening of his cream. It may not be long until the farmer may apply to his laboratory for particular nitrifying ferments to be applied to such special purposes as are mentioned above. Because of the extreme minuteness of these organisms, the too practical agronomist may laugh at the idea of producing fertility thereby, and this idea, indeed, would be of no value were it not for the wonderful facility of propagation which an organism of this kind has when exposed to a favorable environment. It is true that the pure cultures which the laboratory would afford would be of little avail if limited to their own activity, and it is only in the possibility of their almost illimitable development that their fertilizing effects may be secured."

It is of interest in this connection to recall the fact that a few months ago the realization of the prophecy above made was accomplished. There is now made, and offered for sale to farmers, a nitrifying ferment called nitragin, which is prepared from the tubercules of certain leguminous plants. It is found that this material is of use only when applied to crops similar to those from which it is made, while it does not act upon other crops, especially those of a non-leguminous nature. For instance, if the farmer wish to fertilize his clover field with a nitrifying ferment prepared in this way, he must get one which is prepared from clover. If it be a field of peas or beans, on the other hand, he must secure a ferment prepared from these vegetables. This process may seem ridiculous to those who do not carefully consider all of its aspects, but in a little phial, no bigger than a goose-quill, can be easily contained the seeds of ferments, which, by proper multiplication, will produce an active nitrification over a large area. In the preparation of the ferment it is best to mix it with fine, moderately moist soil. After thorough mixing, this soil is then sowed over the land as one would sow wheat or oats. By the process of fission the organisms which are thus introduced into the soil rapidly multiply, and if they find the rootlets of plants suitable to their environment they at once attach themselves thereto, where new tubercules similar to the ones you saw upon the screen, are formed. It is too early yet to speak of the commercial success which will attend this method of fertilization, but there is no doubt of the fact that when a field which contains an abundance of nitrogenous matter becomes practically sterilized, this matter may be rendered more available by the introduction of proper nitrifying organisms, and it is also certain that when those crops, such as the leguminosæ, which are suited to the development of the colonies of tubercules upon the rootlets, are seeded with the proper organisms, the number of tubercules is increased, their activity favored, and the assimilation of atmospheric nitrogen hastened.*

* Photographs were exhibited upon the screen to show the influence of inoculating different plants with different ferments developed on radical tubercules.

Ferments Inimical to Agriculture.—It has been noticed by many observers that when nitric acid is subjected to certain fermentative processes it becomes decomposed and gradually disappears. In studying the causes which lead to this decomposition, it is found that it is due to the action of a micro-organism or ferment, which, by reason of the result of its functional activity, is called a denitrifying organism. While it is true that in numbers and activity this denitrifying organism does not equal its nitrifying relation, yet it is a matter of no inconsiderable importance to know fully the laws which govern its existence. As in the case of the bacteria which are found in ripening cream, where some produce evil and some good effects, so it is with those in the soil. The favoring organisms, whose functional activity prepares nitrogen in a form suited for plant food, are accompanied by others, doubtless nearly related to them, whose functional activity tends to destroy the work which the first have accomplished. It thus happens that in the fermentation of nitrogenous bodies there is danger of losing, as has already been said, a part of the nitrogen, which may either escape as gaseous oxides unsuited for the sustenance of plants, or even as free nitrogen. The object, at least the practical object, of the investigation of these denitrifying organisms, should be to discover some process by which their multiplication could be prevented and their activity diminished. At the present time all that is known is that in ordinary circumstances these organisms are not developed in sufficient numbers to prove very destructive. It has already been mentioned, however, that in case of a very great excess of organic nitrogenous matter a considerable quantity of the nitrogen therein contained may, through the action of these organisms, be lost. The practical lesson taught here is to apply nitrogenous foods in a moderate manner and avoid every unnecessary excess.

In the case of nitrifying ferments, it has been seen that nitric acid and carbon dioxide are some of the final products of bacterial activity. In the denitrifying process, on the other hand, free hydrogen and free nitrogen are the results of the final activity of the micro-organisms. In these tubes

which I show you, which are partly filled with gas, the evolution of the gaseous material has been secured by introducing into the sterilized solution containing a nitrate, a denitrifying ferment obtained from a soil taken in proximity to a stable. Experience has shown that stable manures of all kinds contain these denitrifying ferments, and that these are capable of causing considerable waste of nitrogen, unless care is taken in their use. The results of such experiments as these show conclusively that it would be a useless extravagance to use a fertilizer containing nitric acid, such as Chili saltpetre, in connection with stable manures.

Pathogenic Ferments.—There are also other forms of ferments in the soil of an objectionable nature which are not related to the nitrifying organisms. It has been observed in France that, in localities where animals are interred which have died of charbon, the germs of this infectious malady persist in the soils for many years, and that, especially when cereal crops are cultivated upon such soils, there is great danger of contaminating healthy cattle with the same disease. In one case it was observed that many sheep which were pastured in a field in which, two years before, a single animal which had died of charbon was buried, were infected with the disease and died. In like manner, it is entirely probable that the germs of hog cholera may be preserved in the soil for many years, to finally again be brought into an activity which may prove most disastrous for the owners of swine. Every effort should be made by agronomists to avoid infecting the soil by carcasses which are dead from any zymotic disease. Cremation is the only safe method of disposing of such infected carcasses. The investigations of scientists have shown that there are many diseases of an infectious nature due to these germs, and that these germs may preserve their vitality in the soil. Among others may be mentioned yellow fever and tetanus, and the microbe producing the bubonic plague, which retains its vitality in the soil and thus escapes entire eradication.

Use of Sewage as Fertilizer.—For the reasons given above, the agronomist, who also has at heart the health and wel-

fare of man and beast, can hardly look with favor upon any of the plans which have been proposed for the use of sewage from large cities for irrigation purposes. There is scarcely a time in any large city when some infectious disease, due to the activity of germs, does not exist, and the sewage is liable at all times to be contaminated therewith. In view of the fact that the vitality of the germs mentioned above may be continued for a long time in the soil, it is fair to conclude that it is of the utmost importance to avoid the contamination of the soil, where it is to be used for agricultural purposes, with any of the dejecta which may come from those infected with any zymotic disease whatever.

Supplying Lost Nitrogen.—It is evident that if no process of supplying the loss of nitrogen existed, the soil would soon lose its power of furnishing food and raiment for man. The philosopher who studies the system of nature sees in the far future the advent of a time when the environment of man on the earth will be too harsh for his present organization. The slow cooling of the sun, and, consequently, of the earth, is the principal cause of this misfortune. But added to this must be considered the gradual disappearance of carbon dioxide and organic nitrogen, two of the essential components of the environment which makes plant life possible. Diminishing heat and light, disappearing carbon dioxide and organic nitrogen are little by little making the struggle for existence harder.

Nitrogen is lost not only by the action of the denitrifying organisms, but also by the solution of nitrates and their loss in drainage waters. From the sea this loss is restored in part by fish and sea-weeds. This is a practical illustration of the text: "Cast thy bread upon the waters, and it shall return after many days." The organisms that oxidize atmospheric nitrogen supply another part.

Fortunately, living organisms adapt themselves to changes in their environment, and life, therefore, will still be possible when the present conditions of existence shall have disappeared.

A careful study of the causes which produce a waste of nitrogen and those which restore the loss, gives the pleas-

ing assurance that the present kind of man will not die of nitrogen hunger. Some of the best producers of proteids flourish at high latitudes.

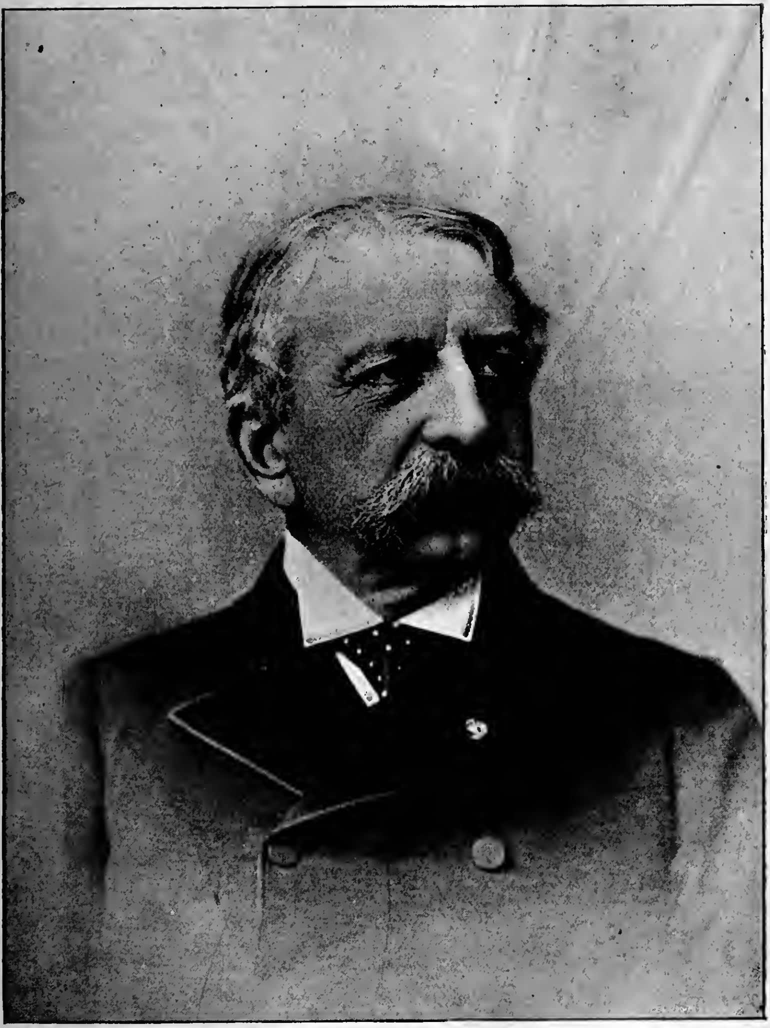
When the last man of the present race, with a stature diminished by long ages of hopeless labor, and with features pinched from hunger and cold, shall have been driven to the equator by the advancing armies of ice, his last look will be at the mocking disc of the sun, denying him warmth, and his last mouthful of food will contain the proteids of oatmeal.

[The lecture was fully illustrated with experimental cultures of soil microbes and by means of lantern slides.]

CHARLES HENRY BANES.

It is fitting, on the death of a public man, that some record should be made of the services he has rendered his fellows. For this reason, the Franklin Institute has appointed a committee to prepare, for permanent record, a brief account of the eminent services the late Charles Henry Banes has rendered it. In presenting this record of the life of their late fellow-member, the committee recognizes that any mere recital of the varied abilities of the man will but inadequately express the extent and value of his public work. In preparing the record the committee has thought it best not to limit the recital to the work he performed in connection with the Institute, but to include therein some reference to his labors and public services in other fields.

Charles Henry Banes was born in the city of Philadelphia, October 24, 1831. He received a public school education, and was graduated from the Central High School of Philadelphia in 1847. At the close of his school life he became interested in mercantile pursuits, in which he continued to be engaged until the breaking out of the war of the rebellion in 1861, when he entered the United States service as Captain of Company E, of the 72d Regiment of



CHARLES HENRY BANES.
1831–1897.

[President of the Franklin Institute, 1886.]

Pennsylvania Volunteers, continuing in the service until June, 1864.

His faithfulness, gallantry and ability in military life are matters of historical record, so that it will only be necessary here to give the following summary. He commanded his company at the siege and capture of Yorktown in 1862, and in the battles of Fair Oaks, May 31, 1862; Seven Pines, June 1st, 8th and 9th; Garnet Farm, June 15th and 18th; Savage Station, June 28th; Peach Orchard, June 29th; Glendale, June 30th; Malvern Hills, July 1st; Chantilly, September 1st; Antietam, September 13th and 17th, and Fredericks, December 13, 1862.

On the 26th of December, 1862, having received honorable mention for gallantry in the Battle of Fredericksburg, in which engagement he was wounded, he was appointed Assistant Adjutant-General, and confirmed by the Senate May 15, 1863.

He took part in the battles of Chancellorville, May 12, 1863; Haymarket, June 24th; Gettysburg, July 2d and 3d, when he was again wounded and honorably mentioned for bravery and gallantry.

He was also engaged in the battles of Robertson Tavern, November 26th; Mine Run, December 2d, where again he was honorably mentioned, and in the Battle of the Wilderness, May 5 and 7, 1864; Spottsylvania, May 8th to the 18th; Po River, May 9th; North Anna, May 23d and 27th; Tolopotomy, May 28th; and Cold Harbor, June 1st to the 4th, 1864, where he was so severely wounded as to be incapacitated for further service. He was breveted Major for his gallantry at Gettysburg, and Lieut.-Colonel after the battle of Spottsylvania.

On his retirement from military life, Colonel Banes became a partner in the firm of George W. Fiss & Co., and shortly afterwards in that of Davis, Fiss & Banes, wool merchants, with which he remained until June, 1872, when he and others began the manufacture of worsted yarns, under the style of Fiss, Banes & Erben. In 1883, he retired from the active duties of this business and became a special partner in the succeeding firms of Erben, Search & Co., and Erben,

Harding & Co. In addition to these business enterprises, he was President of the United States Electric Light Company, and a director in various manufacturing companies, as, for example, the Keystone Watch Case Company, and the John B. Stetson Company.

Nor did he limit himself to undertakings in the manufacturing world; he was also a financier of marked ability. He played an important part in the reorganization of the Hestonville, Mantua and Fairmount Passenger Railway Company, and, at the time of his death, was President of the Market Street National Bank, of which he was one of the originators. He was also one of the directors of the Philadelphia Trust, Safe Deposit and Insurance Company.

In the field of literature he prepared, among numerous other works, "A History of the Philadelphia Brigade," which is justly recognized as of great value, both on account of its historic accuracy and its literary merit.

As to his public life, in 1882, Colonel Banes was elected a member of the Philadelphia Select Council from the Fifteenth Ward, in which capacity he served with distinction to himself and benefit to the public. At various times during his life he was offered the nomination for important offices in the gift of the people, among which may be mentioned that of Controller of the City of Philadelphia in 1884, and that of Mayor of the same city in 1887. He declined these honors.

Colonel Banes was a forcible public speaker, and was much sought after in church, military and civic circles, for addresses. These were always characterized by a charm of expression, logical conclusions and impressive delivery.

In the religious world he was well known in both his own denomination (the Baptist), as well as in evangelical religious circles generally. For a number of years he was President of the City Baptist Mission, in which connection he supported a number of missions, several of which afterwards became large and well-established churches.

As Secretary of the American Baptist Publication Society, he instituted many important business changes, among the most important of which was the construction of

a commodious and well-equipped building at Lombard and Juniper Streets, for the printing and book-making departments of the society. He had plans prepared for a twelve-story office building, at 1420 Chestnut Street, the site of the society's former building. These plans were accepted by the society, and the building is now in process of erection.

Colonel Banes became a member of the Franklin Institute in October, 1874. He was elected to the Board of Managers of the Institute in January, 1877, and continued a member of this body until 1895, when he declined re-election on account of press of business and ill health. He was President of the Institute during the year 1886.

In connection with the work of the Franklin Institute, Colonel Banes is, perhaps, best known, on account of the marked ability, the untiring energy, and the rare executive powers which he exhibited at the International Electrical Exhibition, held in Philadelphia in 1884. Considered from the standpoint of the Franklin Institute, this exhibition may justly be regarded as the most important public work the Institute has ever undertaken. Considered from the standpoint of the electrical world, this exhibition has, probably, done more in advancing the cause of electrical science, by placing on public exhibition the products of electricity from different parts of the world, than has any exhibition held prior to 1884. Nor was this due entirely to the exhibits. At the same time, as a natural outgrowth of the exhibition, a National Conference of Electricians was held under the direction of an United States Electrical Commission, created by an Act of Congress, and approved by the President in May, 1884, the Act authorizing the appointment of a scientific commission, "Which may, in the name of the United States Government, conduct a National Conference of Electricians in Philadelphia in the autumn of 1884."

To those familiar with the excessive labor necessary to carry out successfully the details of a great exhibition, the rare executive ability required properly to select the numerous assistants necessary for the different departments, and the tact and skill required to see that the work is carried out along carefully pre-conceived plans, the pronounced suc-

cess of this exhibition is in itself sufficient evidence of the many-sided abilities of Colonel Banes, who, as the Chairman of the Committee on Exhibitions, and the executive head of the enterprise, proved beyond question both that he was an able business man and a leader of men.

Recognizing the rare opportunities the exhibition afforded for advancing the educational interests of the city, Colonel Banes made arrangements with the Board of Education of the city of Philadelphia to set aside special days during which the students of its public schools could attend the exhibition. Under these plans, upwards of 17,000 students, representing nearly 100 schools and 740 teachers, availed themselves of the opportunity the exhibition afforded as a great object lesson. In order to enable the school children to understand more clearly the general exhibits, a special course of lectures on elementary electrical subjects was provided free of charge, and a prize was offered the students for the best composition on "What I Saw at the Electrical Exhibition."

Nor did the educational features of the exhibition end here. Besides a historical exhibit of electrical apparatus, there was undertaken, under the direction of a committee on bibliography, a collection of electrical books, which resulted eventually in the formation of "The Memorial Library of the Franklin Institute," a library devoted entirely to electrical publications, which holds a high rank among the electrical libraries of the country.

In order still further to instruct the public as to the general nature of the exhibition, in addition to lectures delivered to the general public by noted scientists, the various exhibits were placarded as to their names and the purposes for which they were constructed. Posters were displayed, describing in simple terms their general construction and operation, and, in addition, a series of electrical primers was published and distributed at a nominal cost.

This development of the educational side of the exhibition, which was its characteristic feature, was due largely to the initiative of Colonel Banes as Chairman of the Committee on Exhibition. Under his leading, the exhibition building

became a great school, where the public was able to learn what had already been accomplished by the potent agency of electricity, as well as to form some idea of what was in store for them.

During the exhibition, a valuable series of measurements and tests of electrical apparatus were made, and everything was done to aid the public in obtaining an insight into what they were examining.

From the standpoint of financial success, which, in these days of active business enterprise, is, perhaps, what best shows the ability of a general manager, Colonel Banes' ability may be judged from the fact that the number of paid admissions to the exhibition was 282,779, while the cash receipts from the sale of tickets were nearly $100,000.

During the many months the exhibition building was being erected; during the time that the space was being allotted to exhibitors; while extended correspondence was being carried on with different governments and exhibitors all over the world, and while plans were being laid for the proper carrying out of the financial, mechanical and electrical features of the exhibition, the tact, administrative ability and untiring activity of the chairman were daily manifested, and so assiduously did he apply himself to the work, that before the close of the exhibition his health failed and he was seriously ill for a long time afterwards.

The committee recognizes the inadequacy of this brief record of the work of a many-sided man, a man who attained distinction in the business, financial, military and scientific world, and last, but not least, who was a true Christian. It is willing, however, so far as his connection with the Franklin Institute is concerned, to let the record of the work accomplished by the International Electrical Exhibition of 1884 stand as a record of the services he has rendered to the institution of which he was so long an honored member.

But it was in private life that the most attractive qualities of the man were displayed. His kindly, sympathetic nature, the purity of his life, his unselfish care for his friends, all showed in him the development of a high type of Christian manhood. These peculiarities were best known to his

intimate friends, and are indelibly recorded in their fondest memories.

(Signed) EDWIN J. HOUSTON,
W. P. TATHAM,
H. R. HEYL.

NOTES AND COMMENTS.*

ELECTRIC LIGHTING AND TRACTION.

In the course of a review of the progress of science and the industries during the year 1896, the Philadelphia *Evening Bulletin* contains the following data of interest bearing on the caption of this article:

In the electric lighting field the total capital invested in the United States is given as over $500,000,000. The number of plants, public and private, is over 10,000. The number of motors in use is estimated at about 500,000, and their value at about $100,000,000. The electrical apparatus used in mining is estimated at $100,000,000, and the value of the electric elevator industry will probably not fall short of $15,000,000.

The most important of all the electrical industries, however, is that of electric railways. In this field the investment is very great, and in the United States is represented by a capitalization of over $700,000,000. The number of trolley cars in use is now over 25,000, and these run on over 12,000 miles of track. The electric railways represent more than 90 per cent. of all the street and suburban railroads of the country.

The aggregate of all the capital invested in electric lighting, electric railways and electric power is about $1,500,000,000, and this does not include the value of establishments that manufacture the machinery and apparatus. As many of these are among the largest industrial enterprises in the world, and as nearly all are concerns of considerable magnitude, it is evident that their combined capital will run into large figures.

Now, however, we seem to be on the verge of a practical solution of the problem of obtaining "cold light," or light in which the waste of energy in the form of heat is reduced to a minimum. The earliest exhibited attempt of this kind was the etheric light of D. MacFarlane Moore, of Newark, N. J. Mr. Moore employs as a source of light the vacuum tube, in which, as is generally known, the light is produced by the passage of the electric discharge through the rarefied gas of the tube. In such light there is no combustion and only very little heat.

Another contribution to the same problem is the fluorescent bulb of Mr. Edison, an outcome of his study of the X-ray tubes. The commercial possibilities of these inventions, however, are not yet known.

* From the Secretary's monthly reports.

ELECTRICAL ENERGY DIRECTLY FROM CARBON.

At a recent meeting of the New York Electrical Society, Mr. Willard E. Case presented an interesting paper on "Electricity from Carbon Without Heat."

We give herewith the editorial comments on the paper, expressed by the *Electrical World.* The author paid some attention to the carbon cell recently revived by Mr. Jacques, but added little toward explaining the curious results which are obtained in this form of battery. He finds that if water be present in the caustic soda when first used, the reversion of the electromotive force which Mr. Reed found to exist becomes manifest, and he believes that its presence is the cause for this phenomenon, similar in its nature to that which takes place in the case of a thermo-electric couple. If caustic soda be fused in a nickel crucible, the nickel is not acted upon by the alkali, and therefore acts as an inert negative. Under these conditions no reversal of polarity could be detected; but as the temperature is increased the electromotive force rises to a maximum and then diminishes, finally becoming apparently asymptotic to the temperature axis. This fact is opposed to that presented by Mr. Reed, who found a reversal of the electromotive force as the temperature increases. The discrepancy may possibly be explained upon the assumption that the radiation of heat from a nickel crucible in Mr. Case's experiments is sufficient to prevent an increase of temperature above a certain point. The erratic performance of the cell in which an iron vessel is employed clearly showed that there remains considerable room for investigating the action of this type of carbon battery. One of the most interesting and suggestive points which Mr. Case brought out is the possibility of discovering a method of obtaining electricity from carbon without heat, by following nature's plan in the human system, and instead of having the entire transformation take place within the carbon-conveying cell, previously prepare outside the cell the material to be used.

ELECTRICAL NOTES.

Houston and Kennelly have lately presented to the American Philosophical Society an elaborate paper, in which they have sought to demonstrate that *the insulating substance* surrounding an electric conductor *is the true path of the current.* The Edison Company, of New York, is reported to be substituting the Thomson *mechanical wattmeters* in place of the old chemical meters. Following out the interesting experiments of Becquerel, which showed that certain salts of uranium, after exposure to sunlight, emitted radiations which, like the *Röntgen rays,* were capable of affecting photographic sensitive plates through intervening opaque substances, Professor McKissick, of Auburn, Ala., as the result of numerous experiments, announces his belief that the Becquerel ray is the connecting link between the ordinary light and the Röntgen ray. A full account of Professor McKissick's experiments appears in a recent impression of the *Electrical Engineer.*

ORIGIN OF PETROLEUM.

Much of scientific interest attaches to certain recent investigations designed to throw light upon the mode of origin of petroleum. Mendeléef endeavors to answer this question by assuming a mineral origin for petroleum, through the chemical interaction of steam upon metallic carbides assumed to exist at great depths.

Engler has recently demonstrated experimentally the artificial production of hydrocarbons of the paraffin series in the destructive distillation of animal fats under pressure. This interesting fact greatly strengthened the view of many chemists, that natural stores of petroleum had their origin in the decomposition of animal remains under peculiar heat and pressure conditions.

Sadtler now supplements the work of Engler by demonstrating that petroleum hydrocarbons are produced in the destructive distillation, under pressure, of linseed oil, a product of vegetable origin.

The results obtained by Sadtler, therefore, would permit the conclusion that native petroleum was derived from the decomposition of vegetable remains and reopens the whole question. W.

THE BRADLEY ALUMINUM PATENT DECISION.

A recent decision of the United States Circuit Court of Appeal, confirming the ownership by the Cowles Electric Smelting and Aluminum Company, of certain patents issued to Charles S. Bradley in 1891-1892, may have an important bearing, not only upon the aluminum industry, but also on a number of related industries, notably on the manufacture of carborundum, calcium carbide, and other products which depend upon what is technically known as "electric smelting."

Passing by certain special points at issue in the case, the vital element embodied in the decision is the broad interpretation placed upon the Bradley patents, and which, if we properly apprehend it, will permit its owners to manufacture and to license others to manufacture any and all the metals and compounds which may be produced by the process of electric smelting from highly refractory ores and compounds, which are non-conductors in their unfused state.

To what extent this decision may interfere with the industries already established can only be conjectured at this time, and the consideration of this phase of the subject is foreign to our purpose.

Briefly stated, the Bradley invention, which bears most directly on the aluminum industry, contemplates the reduction of refractory ores (of which the ores of aluminum may serve as an example), which are non-conductors in their unfused state, by fusing the mixture, utilizing the heating action of the electric current, and then decomposing the fused compound by the electrolytic action of the same current. The process is made continuous by charging the bath with fresh quantities of the ore or compound as the reduction proceeds. The gist of this invention, from this, would appear to be to do away with the serious difficulties attending the use of heat externally ap-

plied to effect the fusion of many refractory ores (such as those of aluminum), by using for this purpose an electric current of greater quantity than will be needed to effect electrolytic decomposition after the fusion is once made. Thus, the current is caused to perform two distinct functions: one fraction of the electrical energy is continuously expended in fusing and maintaining the fusion of the refractory mixture, thus rendering it conductive; while the remaining fraction effects the electrolytic decomposition.

To those familiar with the operative details of the electrolytic method in vogue for the manufacture of aluminum, the completeness with which all the essential features are covered by this invention will need no further comment. The fifth claim of this patent (No. 468,148, February 2, 1892) might well stand for a concise description of the present electrolytic process by which aluminum is now exclusively manufactured, viz.:

> "(5) The continuous process of separating or dissociating aluminum from its ores or compounds, consisting in fusing and maintaining the fusion and electrolytically decomposing the ore or compound by the passage of the electric current therethrough and charging the bath with fresh quantities of the ore or compound as the reduction proceeds, substantially as set forth."

Two other patents are considered in the same decision, into which it will be unnecessary to enter.

The court's interpretation of the scope of the three patents would appear to cover not only the ground referred to in the foregoing allusions to aluminum, but also the process of "electric smelting" in general, it being held that "the language of the Bradley claims is broad enough to admit the admixture of carbon, if his invention was a primary one, and the employment of carbon was a mere auxiliary of the current in effecting the reduction."

W.

TELEGRAPHY WITHOUT WIRES.

An article in the March number of *McClure's Magazine* describes the experiments now being conducted in England by Gugliemo Marconi for telegraphing without wires, to which the following reference appears in the *Electrical World:*

At the Liverpool meeting of the British Association, Mr. W. H. Preece called attention to these experiments, which have been conducted since with his collaboration. Mr. Marconi's results are remarkable. He seems to have discovered a new form of electrical wave, somewhat similar to the Hertzian wave, yet differing greatly in its penetrative power. On Salisbury Plain he has succeeded in sending intelligible signals a mile and three-quarters, while during some former tests signals were exchanged between two points separated by a hill three-quarters of a mile thick. It is the belief of the inventor that his new waves will penetrate all substances.

The inventor and Mr. Preece are now working at Penarth, in Wales, to establish regular communication with a lightship some miles at sea. It has been proposed to establish, in connection with lighthouses, a constant source of

electrical waves, which will penetrate the densest fog and make themselves evident on shipboard to proper receivers.

In regard to the use of this system in naval operations, Mr. Marconi speaks of a curious danger to be apprehended from induction sparks, which might explode the magazine of a warship.

ELECTRO-CAPILLARY LIGHT.

In a contribution to *Wiedemann's Annalen*, No. 12, Herr O. Schutt, of Jena, describes a new electric discharge phenomenon, which he terms electro-capillary light. When the discharge of an induction coil is sent through a narrow capillary tube of about 0·05 millimeter in diameter, provided with aluminum or copper electrodes and filled with air under ordinary pressures, an intense luminosity of the thread of air is obtained—a luminosity which is intrinsically far superior to that of the arc, and would form an exceedingly powerful source of light, if it could be made continuous. The narrow capillaries deteriorated rapidly, roughening inside, and were blown into a series of spherical enlargements. Wider tubes gave less light, but were much more permanent. At the same time the bright lines in the continuous spectrum in the original light became more prominent. At pressures above one atmosphere the phenomena were nearly the same, but the sparks passed with greater difficulty. At low pressures the light became less intense, the continuous spectrum faded, and the bright lines shone out more distinctly. The kind of glass is immaterial. It is stated that the tubes may be made 20 centimeters long and make splendid line sources.

THE LAKE WATERWAY.

Probably no expenditure ever made by the Government, says the *Engineering and Mining Journal*, has been of greater benefit to the nation than the money employed in improving and maintaining navigation on the Great Lakes. It is the lake waterway which has made the development of the iron ores of Michigan, Minnesota and Wisconsin possible, and has enabled the iron ranges of the Lake Superior region to furnish the industry in the United States with a supply of iron ores, without which its growth would have been far less rapid than it has been. The copper industry of Michigan has been also very greatly benefited. Taking these two great interests alone, the return has been far greater than the amount invested, to make no mention of the agricultural industries of the West.

The enormous value of the lake traffic is shown by the fact that in 1895—the figures for 1896 are not yet complete—the vessel traffic passing through the Detroit River, where nearly all the tonnage of the lakes meets, exceeded by 10,000,000 tons the total foreign trade of the United States. The freight carried was 29,860,335 tons and the distance covered by it reached the enormous total of 22,395,251,250 ton-miles. This great amount of freight, moreover,

was carried at an extremely low rate, the average being estimated at 0·085 cent per ton-mile—probably the lowest price for which freight is transported anywhere in the world. In this country the railroad rates are less than in any other except British India; but about the lowest charge known here is that on Pocahontas coal to tidewater, which is not far from 0·25 cent, or three times the lake rate. The average trunk line rate on heavy through freight is 0·45 to 0·60 cent, or from five to seven times the lake rate.

The effect of this extremely low rate, on the iron ore industry especially, can be estimated only by the fact that the shipments have reached a total of 10,000,000 tons a year.

The figures which best illustrate the growth of the lake traffic are those which give the business passing through the Sault Ste. Marie Canal. We have given the statement for the years 1885, 1890, 1895 and 1896 to illustrate the growth of business:

Year.	*No. Vessels.*	*Tonnage.*	*Tons Freight.*
1885	5,380	1,035,937	3 256.628
1890	10,557	8,454,435	9,041,313
1895	17,956	16,806,781	15,062,580
1896	18,615	17,249,418	16,239,061

The estimated value of the freight last year was $160,000,000. It must be remembered that the canal is closed by ice for about one-third of the year; in 1896 it was open 234 days.

The only great maritime canal at all to be compared with this is the Suez Canal; and during the latest year for which figures are available, that waterway passed 3,352 vessels, with a total registered tonnage of 8,039,105, or 9,110,313 tons less than were recorded at the Sault last year.

Perhaps these figures should not surprise us, when we remember that over 60 per cent. of the iron ore supply of the United States last year came from the Lake Superior mines, and that nearly all of it took the water route to market. Taking the rates paid on this ore by lake, we find that if the ores had been carried by rail at the usual average of the roads west of Cleveland and the other lake ports, the charges on this ore would have exceeded the freight actually paid by some $2.50 per ton; that is, the cost of every ton of pig iron made from lake ore would have been increased by $4.

This instance alone is sufficient to show the importance of the lake waterway, to both the mining and manufacturing industries, and others equally striking could be given, did space permit.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 17, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 17, 1897.

JOHN BIRKINBINE, President, in the chair.

Present, 102 members and visitors.

Additions to membership since last report, 16.

A letter was read from Mr. Alfred C. Harrison, presenting his resignation as Vice-President of the Institute. The resignation was, on motion, accepted, and, in due form, Mr. Theo. D. Rand was elected to fill the vacancy.

A communication was read by the Secretary, transmitting the following resolution, passed by the Board of Health of the City of Philadelphia, at a meeting held March 16, 1897, to wit:—

"RESOLVED, That the Franklin Institute be requested to appoint a committee to confer with the Board of Health with a view of taking action to abate or modify the smoke nuisance."

The communication was referred to the Committee on Science and the Arts.

Lieut. B. W. Dunn, Ordnance Department, United States Army, presented a paper giving, in brief, an account of investigations conducted during 1891-1892, which resulted in the invention of "A Photographic Method of Measuring the Intensities of Impulsive Forces." The apparatus and its serviceability in measuring the explosive force of various powders were illustrated with the aid of the projecting lantern, and the speaker dwelt especially upon the application of the apparatus in the determination of the resistance of materials employed in engineering works.

The subject was referred for investigation and report to the Committee on Science and the Arts.

Mr. Lewis G. Rowand presented a description of "An Improved Safety Device for Electric Circuits." The speaker exhibited the device, and gave an experimental demonstration of its mode of operation.

Mr. Barnett gave a brief oral account of the evolution of the mechanisms employed in the so-called "Portable Fire Extinguishers," with especial reference to an improved form of this apparatus, manufactured by the Stempel Fire Extinguisher Manufacturing Company, of St. Louis.

The Secretary reported certain experiments devised and shown in a lecture delivered before the Institute, by Prof. Jacobus, of the Stevens Institute of Technology, illustrating the comparative value of the Welsbach incandescent gas light and the acetylene light, in rendering colors and shades of colors, demonstrating not only that these modern illuminating methods were greatly superior in this respect to coal-gas and the incandescent electric light, but also that there was very little difference between them.

Adjourned. WM. H. WAHL, *Secretary.*

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THE CHEMISTRY OF THE POTTERY INDUSTRY.*

BY KARL LANGENBECK.

The discovery of porcelain and the beginning of its manufacture in Europe was through the labor of a chemist, Friedrich Böttger, the story of whose quest for gold for the elector, Augustus II of Saxony, and the practical results of his experiments, is an oft-told tale.

Perhaps from the profession of its discoverer as a first reason, but certainly from the spirit that it should profit by all the assistance that science could render this beautiful art, the pet of the states and princes of the last century, the porcelain factories of Europe were among the first industries, except the pharmaceutical and metallurgical ones, to benefit by the constant assistance of chemists.

The national factory of France, at Sevres, was, from its beginning to the present time, almost constantly under the

* A lecture delivered before the Franklin Institute, January 29, 1897.

direction of men who ranked among her ablest chemists. And yet, the pottery industries at large, although they offer many problems whose solution lies purely within the province of the chemist, have given him practically no opportunity of adapting his researches to assist in lightening the difficulties that beset them. And it is only within very recent years that chemists themselves, who had rendered such signal service in the development of the most difficult and aristocratic of ceramic products, porcelain, felt tempted to extend their interest seriously and extensively to the more common but far more important products of the industry, from purely scientific interest. Yet, not until the field of ceramic labor was so extended by chemists themselves can their efforts even on behalf of porcelain, successful as they had been in their *results* in obtaining a beautiful product and rational manufacture, be said to have borne fruit from a chemical standpoint. For after all, if you consider the labor of even the most distinguished of the older chemists who devoted themselves to this work, Brogniart and Salvetat, they only assisted empiric experiment with general chemical reasoning and with analytical control of the various raw materials that were used.

Not until a later chemist, Dr. Herman Seger, who had directed his main energies to a study of the commoner clay wares, made his classic investigation on the nature of Japanese porcelains, was something like scientific light shed on the constitution of porcelain glazes in general, their relation to the composition of bodies upon which they can be melted without defect, and their chemical formulæ in relation to the general chemical formulæ of pottery glazes.

I take it that an important reason why chemists have had little opportunity to make themselves useful in the field of pottery manufacture, lay in the fact that the acquirements of one who would render service must lie in so many directions, and be coupled with so much practical experience relative to the physical and mechanical treatment of materials, that a knowledge of chemistry, without a practical apprenticeship in the craft, seemed a rather insignificant weapon with which to attack difficulties that are often like

the hydra, hundred-headed, and in which the chemical side is but a single factor. And this was particularly the case before something like a scientific groundwork had been laid of the constitution of pottery glazes.

Furthermore, experiences which have been made under the anxious strain of great commercial risks, as those of the potter very commonly are, in his having to submit to the uncertain element of fire, large quantities of ware upon which he has spent much labor, made in mixtures that are tentative, of materials uncertain in composition, and that to a single burning which, like the cast of a die, may win or lose, make a man timid, doubtful and secretive about the method of his results. And if the results of years of anxious experiment are reducible to the knowledge of a few particular materials and a few formulæ for mixing them, to the several components and colors of his ware, which he can record on a little slip of paper and carry in his vest-pocket, while he carries the standard for the measure of the fire, for perfecting them, in his eye, it is but natural that the maker of experiences which come down to such an absurd compass, and yet are so momentous to him, will have an exaggerated opinion of the value of receipts and of particular results instead of general methods. As he looks back upon the chaos of haphazard trials that have led him to his final results, he cannot believe that such experiments can be reduced to an orderly system. And he generally does not wish to know that such a system will accomplish, in a few hours of calculation and a few weeks of experiment, all that he required years to achieve. It would seem a mockery to his intelligence and a belittling of his most serious efforts. Fancy the wrath and contempt of Christopher Columbus, translated to this century, for a Cook's tourist who had made his tenth summer vacation trip to Europe!

Hence, I take it that the very risks and difficulties of the potter's craft gave its members so conservative, suspicious and secretive a temperament, that they were not willing to lay their experiences before a professional adviser, with the unreserved freedom that is essential to all theoretic service, whether it be a client disclosing his business transactions

to his attorney, a patient detailing his symptoms and habits to the physician, or a manufacturer laying his methods, his experiences and aims before the chemist or engineer. And so it is a curious chapter in human limitation, that while *chemists* solved the problem of making *porcelain*, though the skilled potters of Delft and of all Europe had failed, these, nevertheless, held aloof from seeking the service of the men who accomplished the most difficult feat in their own craft.

The pottery industries, instead of being among the first to find a field for the chemical engineer, as they logically should have been, are among the last. In Germany and France it is probably not twenty-five years since potters have thought of such a thing; in England and with us, it is not seriously considered yet.

After the passage of that celebrated English law, later copied in this country, which compelled manufactures of foreign make to be stamped with the name of the country of their production, England awoke to an astonished realization that the best of the wares she had approvingly fancied came from her celebrated Staffordshire district were "made in Germany"—by a country poorer in clays and fuel, whose labor and products she had always been content to look down upon as being what Professor Reulleaux had once stigmatized them with being, *billig und schlecht*—cheap and bad.

The reason of Germany's rapid and successful industrial development is well known, and it should be a source of hopeful satisfaction with us in America that while most of our industries have grown on English models, we are not so stereotyped in their adoption but that we are able to improve them by the aid of applied science and art from without the trammels of the particular craft, which England seems much less able to do. Our pottery industries are, perhaps, more distinctly English than any other. Our ware, our methods, the majority of our pottery workmen, are English.

The enterprise, diligent persistence and skill in empiric experiment which are characteristic of English industry, and have brought her pottery work to reputable perfection

and given some of the achievements high celebrity in ceramics (Wedgwood, Royal Worcester, Crown Derby, etc.), are qualities that have not left the men who brought the art to this country and have raised it to great commercial importance.

The time is now ripe for the application of scientific methods to its processes, as empiric ones can scarcely accomplish more than the results of our English prototypes, which we have already reached. Competition from our Continental rivals, with whom more scientific methods obtain, besets us. Artificial political barriers are foolhardy and a wrong, if they undermine the energy that prompts men to seize and learn all instruments for perfecting their craft.

The Franklin Institute, which has labored so long and so successfully in the cause of applying science to our industries, will, I am very sure, find it a grateful task to stimulate its aims in a field of great industrial importance that is, as yet, quite new.

Let me remind you what the material entering into the making of pottery is, and call your attention to the more common problems and difficulties that beset the potter. It will then be possible to give a brief survey of the resources that chemical methods and reasoning open for the solution of the technical questions that arise with him.

All ceramic products are, of course, fashioned from clay and are hardened to permanent form by baking or burning. But no raw material varies so widely in composition and physical properties as do the clays, and the products of no other material are put to uses as widely divergent, calling forth all the characteristics of its different kinds and those developed by the different treatment and degree and quality of burning to which they may be subjected.

Unlike every other mineral, it is never a question—is it rich enough or pure enough for the one or two objects of its utility? You may say, *a priori*, every clay has properties that make it of particular value for manufacturing some article of use. But the very wealth of its industrial application, and the variety of qualities which it can be made to exhibit and are the condition of its extensive and varied

use, have so overwhelmed men that they abandon hopelessly almost every attempt at an orderly and systematic investigation of the qualities which a particular clay deposit has, and pitch upon a use for it in the most haphazard way; or in selecting a clay for some particular use, go at the work in the blindest empiricism.

You can best appreciate this by investigating the commercial history of the clay industries. I think you will find that most factories have passed through one or two crises; that many are producing some other product than the one they were originally built for; that nearly all of them have paid so dearly for their technical experience; that their capitalization is higher than it should be, and that the cost of production is affected by the evil of having to perpetuate the consequences of a situation irrationally chosen and a factory system based upon the manipulation and burning of a material that had afterward to be abandoned without being able to abandon the machinery and kilns adopted for it. Thus much for the difficulties that the very abundance and variety of *the* pottery material par excellence raises; and if the difficulty of selecting the right kind, determining its proper mode of working and the kiln and temperature for burning it for a definite purpose, is already great, it will occur to you that these considerations are largely complicated, when, as in most cases, the clay is to be incrusted with other clays and glazes, and decorated, perhaps, with colors and enamels. Questions of shrinkage, of coefficient of expansion, chemical action and solution by the fusing glasses, come into play.

In the modern ornamental building brick and the vitrified ones, fast becoming our most important paving material, ordinary floor tile and drainage pipes, you have but the first considerations. But in all that you commonly think of, when one speaks of pottery, the thousand and one *containers*, of domestic, ornamental and industrial use, from the acid still and pump of the chemical factory to the soup tureen, the Dresden clock case or the Crown Derby vase, you have a clay form or body, covered with a glass or glaze, and often a decoration in color over or under the latter.

The following are some of the problems which the potter must solve: Architects require the ornamental terra-cottas and friezes upon buildings in great varieties of color. The clays which would produce them are, in the majority of cases, too expensive or often absolutely impractical for forming and burning the heavy pieces required. It, therefore, becomes necessary to make the body of the terra-cotta of a clay or mixture of clays that will have the necessary physical qualities, and prepare a series of encrusting clay mixtures that will adhere to it without defect, and produce, under the fire at which it must be burned, all the required tints.

All clays shrink considerably, both in drying and burning, and the shrinkage of clays differs materially not only in the aggregate, but in the different stages of drying and burning. If, therefore, the movements of the encrusting clay are not absolutely in unison with those of the body upon which they are placed, the former will shell off entirely or in parts. As the error does not always show itself at once, and as after the fire it is irremediable, and with it the entire product is lost, the problem is difficult in its subtlety and serious in its miscarriage.

The glaze covering on pottery is very difficult to obtain empirically. It must be a perfect glass in transparence and brilliance. But a *glass*, no matter how beautiful, cannot be melted upon pottery without devitrifying and entirely losing its characteristic qualities. The potter has, therefore, built up his glaze by himself without assistance from the glass-maker, and believes a *glaze* radically different from a *glass*.

But even with transparence and brilliance attained, the problems attaching to the making of the glaze are but begun.

In order to fulfil its principal mission of yielding an impervious coating to the clay body of the ware, which, even in the case of translucent and vitrified porcelain, is not absolutely impervious to the penetration of liquids, it must not crackle through use. In other words, it must undergo the same movements of expansion and contraction as the body upon which it is fused. These movements of a piece of

pottery under the fluctuations of temperature are very slight, it is true, but they are very positive, and transcend the limits of elasticity of both the glaze and the clay body, unless these are very closely adapted to each other in their coefficients of expansion, because of the intimacy with which they are attached to each other.

If the coefficient of expansion of the glaze exceeds that of the body and its movement goes beyond the elastic limit of the latter, the glaze will push off at the edges of the pieces of ware, tearing the clay off with it. And in case the disagreement is great, it will pull off the handles and spouts of the piece, or even shiver the whole to a mass of splinters.

Where the coefficient of expansion of the body is the greater, exceeding in its movement the elastic limit of the glaze, this cracks, and the fineness of mesh of the intersecting lines of fracture is directly in proportion to the degree in which the two are at fault.

This difficulty never occurs with glass itself, for it is due to the interdependence of the two bodies constituting the pottery piece.

It will, therefore, be clear to you that the composition of the clay upon which the glaze is to be used must itself be experimented with and modified to meet what cannot be accomplished by the glaze alone.

When these problems have been solved and a glaze and body perfectly co-ordinated, the decoration of the ware, by printing or painting with ceramic colors, may prove the glaze entirely unsuited to such treatment, and the labor of perfecting it and adapting it and the body to each other entirely in vain.

You will remember that after a piece of ware is fashioned it is commonly fixed to permanence by burning, before the glaze is applied. This first fire, which hardens the clay, is known as the "biscuit fire," and upon the "biscuit" or baked but unglazed ware, decorations which are desired of absolute durability, as in the case of dishes, or of particular brilliance, as in the finer faiences, are applied by printing and hand-painting in ceramic colors. Then the glaze,

ground to creamy consistence in water, is washed over the whole piece, and in a final glost fire it is melted to a transparent varnish, covering and absolutely protecting the decorations between it and the body.

The colors that are used must, in order to resist the high temperature requisite, consist of metallic salts and oxides, and these are all more or less soluble in melting glass fluxes. These colors must, therefore, be mixed so as to resist solution in the glaze that is to be fused over them as much as possible, and this must be of a character that its solvent action in fusing is small, for in this property glass fluxes vary widely. A glaze, perfect in every other respect, which eats off in melting these "underglaze" colors, as they are called, would be utterly useless for ware decorated in this manner.

Again, where glazed wares are to be gilded or decorated in easily fusible enamels and vitrifiable colors upon the glaze, decorations even more extensively practised, the glaze must stand repeated fires, at a temperature lower than its melting point, in which these are fused and fixed without suffering devitrification.

The composition of glass fluxes profoundly affects the tints produced in them by chromogenic oxides, and pottery decorated with colored glazes must be adapted to bearing a variety of these, though all must conform to the fundamental requirements of a uniform coefficient of expansion and being perfect glasses.

The first service that the chemist must render to supply data for the solution of these common problems and difficulties that beset the potter, and which I have enumerated, consists in classifying, or at least describing with positive factors, physical as well as chemical, the host of clays that geological, mining and engineering work are constantly disclosing and that the public is anxious to put to industrial use.

It is to be regretted, but it is, nevertheless, the case, that almost all the labor which chemists have spent upon countless clay analyses for geological surveys, whether at public or private expense, has been practically thrown away, for

the reason that none of them go far enough, and are accompanied with the necessary physical tests and descriptions to classify them, and give the practical worker a mental picture of what they will do under his kiln-heats and under his glaze.

In the first place, an elementary analysis of a clay, which is practically the only kind made, tells the potter little or nothing. Suppose you had a vinegar or a sugar syrup which you wanted analyzed, and the chemist to whom you took it should make a combustion of each and inform you how much carbon and oxygen and nitrogen and hydrogen they contained, what would you do? You would laugh at him.

You want to know how much acid the vinegar contains, and if some of the acid be malic acid, so that you can tell whether it was made from apple cider or not. You want to know, in the case of the syrup, how much saccharine matter it contains, and how much of it is cane sugar and how much glucose. Now all of these substances contain the same elements, carbon, hydrogen and oxygen, but they are grouped into compounds of very different properties, and the proportions of *these* are what you are anxious to know, because these and their amounts determine the value of the vinegar or the syrup.

Now let me explain the business of a chemist to you. He works largely by analysis; that is, by picking things apart, so that you will understand the character of a compound from its components. But there are two kinds of compounds, those which are mixtures and those which are homogeneous chemical bodies. The vinegar I spoke of is an example of the former, the acetic and malic acids it contains are examples of the latter. To pick apart the *mixture vinegar* so you will understand it, you separate the chemical compounds that compose it; to analyze the acetic acid, which is a homogeneous chemical compound, so that it may be understood, it must be resolved into its elements, carbon, hydrogen and oxygen, $CH_3.COOH$. If the chemist resolves the mixture at once into its elements, he goes too far and tells you practically nothing.

It would be like the anatomist who wished to show you

the structure of a chicken, and who, instead of removing the feathers to disclose the naked body, and the skin to display the muscles, and finally removed these to show the viscera and the osseous structure, put his bird into the meat chopper and reduced it to a pulp! His dissection would be so thorough that you could make neither head nor tail of it. Now this is just what chemists, out of touch with the pottery craft, have been doing. Instead of resolving unknown clays for the potter into the skeleton, the plastic muscle and the binding skin, they have put them into the analytical meat chopper and turned out elementary pulp!

Look at any geological or mineralogical book for the composition of a clay, and you will find some such answer as this:

	Per Cent.
Silica	50·02
Alumina	35·18
Oxide of iron	0·36
Lime	0·12
Magnesia	0·07
Alkalies	3·39
Combined water	10·57

And what does all this maze of elements mean? That this natural clay consists of

84 per cent. of true clay substance—*the plastic element*—the muscle.

9 per cent. of fusible mineral, feldspar—*the binding tissue*—which melts on baking and bonds the particles together.

7 per cent. of quartz or flint—*the skeleton.*

Now, you have the unknown clay resolved into its proportions of the three simple components of its structure, and the potter can tell you at a glance that *that* clay will not make a pottery body by itself. The skeleton is far too weak and the binding tissue insufficient; but he can now readily see how much flint and feldspar he must mix with his clay to answer for making his pottery body, and so he is saved much anxious work and tedious experiment by this solution of the chemist. But why has not the chemist answered thus simply and directly long ago? The simple analysis is hard to make, the simple answer the most difficult to find.

The glaze is a far more perplexing material to the potter

than the body, and I have enumerated a few of the difficulties that are encountered with it. It is made of a variety of materials that are difficult to survey, and, though the potter mixes these himself, from the fact that they lose their identity in fusion, it is difficult for him to foresee what the increase or diminution of one or the other will effect in the glaze. These are the constituents of common glazes: potash, soda ash, white lead, zinc oxide, borax, boracic acid, feldspar, Cornish stone, chalk, clay, quartz or flint. A porcelain glaze usually consists only of feldspar, chalk, clay and flint. Complex and different as these bodies are, you have, when they are melted together into a glaze, a homogeneous chemical compound.

In order that this may be surveyed and changed positively and at will to meet the different needs which I have indicated to you, the chemist must render the same service in reasoning about the glaze as he has about the clay and pottery body, namely, reduce it to the few simple elements of its actual structure. But, as the melted glaze is a homogeneous chemical body, like the acetic acid in the vinegar, it will be necessary to go into the chemical elements. Let us examine the very different materials I have enumerated for you as composing glazes—what do they consist of chemically, in all that would remain of them in melting?

The oxides of metals, as in the potash, soda ash, white lead, oxide of zinc, chalk—these the chemist calls "bases." Now, the quartz and the boracic acid are both acids and the borax, feldspar and Cornwall stone contain both bases, that is, oxides of metals and one or the other acid, and, finally, the clay, besides containing an acid—silica—contains the oxide of a metal—alumina—which does not exactly behave like the others, namely, as a base, but seems to occupy an intermediary position between a base and an acid. It is again a connecting link between these two, so the complicated glazes also consist of only three units, though these are composed of chemical *elements*,* as the body or the clay consists of three, though these are chemical *compounds*.

* It goes without saying that this term is not used in its strict chemical sense.

The scientific chemist will take some exception to these trilogies, but they are none the less useful for a practical comprehension of the facts.

Now, let me divide two glazes for you, and show you the application of such a chemical division:

	A	*B*
Borax	24	48
Chalk	25	12½
White lead	33	65
Feldspar	23	
China clay	23	26
Boracic acid	15½	
Quartz	57	63

Here are two glaze receipts. I question whether any potter would venture an opinion if either would give a perfect glass or not on melting, and if so, what the properties of each would be. It is practically impossible to do so, on account of the number and the mixed character of the constituents. But upon resolving them into their chemical divisions and elements, they are easily compared, and the phenomena of their behavior explained even by the potter untrained in chemistry. If he have the glaze mixtures which he uses in his work, and the experimental mixtures which he prepares, constantly reduced for him by a chemist into the fundamental chemical groups that compose them, the empiric receipts which can never be surveyed are resolved into intelligible factors, and a little practice in studying these, in conjunction with the phenomena that the glazes exhibit after coming from the fire, will soon enable him to experiment with a certainty in the direction that his aims dictate, which, without this help, is at the mercy of the blindest chance.

In order to make this reduction of empiric glaze mixtures into simple chemical formulæ, I prefer to do so by making use of the old "combining weights," which unite the combination of the elements by their atomic weights and by valence into one expression, reducing the sum of the "combining weights" of the bases to unity, or, perhaps better, to 10, avoiding fractions and chemical symbols as much as possible, so as not to confuse the practical potter.

The receipts given reduce to the following chemical formulæ:

A

2·5 Potash and soda. 5·0 Lime. 2·5 Lead oxide.	3· Alumina.	30· Silica (flint). 5· Boracic acid.
10·0 Bases.	3· Intermediary elements.	35· Acids.

B

2·5 Potash and soda. 2·5 Lime. 5·0 Lead oxide.	2· Alumina.	25· Silica (flint). 5· Boracic acid.
10·0 Bases.	2· Intermediary elements.	30· Acids.

The potter will find that mixtures varying widely from these in the proportions of their principal groups will not produce glazes under the conditions of the pottery glost fire, and he can spare himself the trouble of trying them.

A glaze that is high in silica is less likely to craze, but more in danger of shivering, so that *A* may shatter a body made of a siliceous clay mixture, upon which *B* stands perfectly. But the latter may craze upon a biscuit proportioned to carry *A*.

When the bases are rich in heavy metals, particularly in lead, and the acids in boracic acid, the resulting glaze has a high refracting index; glaze *B* is, therefore, more brilliant than glaze *A*. But lead glasses have a more yellowish cast than lime glasses, so that *A* is the whiter of the two.

The same factors that increase the brilliance of a glaze, a larger proportion of heavy metal oxides in the bases and boracic acid in the acids, lower the fusing point.

A proportionate increase of boracic acid and lowering of alumina increases the solvent action of the glass for chromogenic oxides. *A* attacks underglaze colors less than *B*, but the latter is the better basis for ornamental colored glazes.

The many phenomena exhibited by pottery glazes can be followed and understood by comparison with their chemical formulæ, but the examples already cited will suffice to show the assistance that a chemical division of their constituents can render in judging them. The same is equally true of the ceramic colors, with which the potter has to deal.

Perhaps the most mysterious of the seats of the potter's trials lie in the fire. This is the proof to which all his ware must be put, and here is the cause of his most perplexing failures. But this element, too, has been resolved by the chemist into its simpler phases, and the measurement of the higher temperatures by simple and accurate means, and the analysis of the flame by simple apparatus that can be put into the hands of any fireman, are accomplished facts, concerning which the potter can get full instruction from the chemist. It would, perhaps, lead us too far to discuss the chemical effects of the quality of the fire upon pottery colors, but I can illustrate its far-reaching results by two pieces of ware that I have here for the purpose, a piece of celadon and one of red Japanese porcelain.

The chemical formula of these two glazes is exactly the same; it is:

3· Potash. 7· Lime. Trace copper oxide.	5· Alumina.	40· Flint (or silica).
10· Bases.	5· Intermediary.	40· Acid.

The only difference in their treatment is that in the glaze fire this green piece was in a flame containing a little more air; it was in what chemists call an oxidizing fire, this red piece was in a reducing fire.

The difference in quality of flame was very subtle, but the result was radical and momentous. Perhaps the money value that the connoisseur would put upon them will tell this better—the red piece is of the order of the celebrated Japanese and Chinese red porcelains, known according to their tints as "ox blood," or "chicken blood," "*sang de boeuf*," or "*sang de poullet*." If the flame had been so perfect that the entire piece had been red, without the white portions, it would be worth several thousand dollars; as it is, it is only worth as many hundred, while the green piece is but worth as many hundred cents.

It is the business of science to disclose practical facts that lie a little under the surface and removed from the observation of ordinary men. It is necessary often to coin new names for these facts, and these sound very perplexing

while they are unfamiliar. But the facts of science and its terminology rapidly become common property of the masses, when there is use for them. You hear street-car motormen and telephone linemen talk of watts, and ohms, and ampères, and fields, and commutators, words only used by a professor of physics ten years ago.

Samuel Pepys tells us that in his time the multiplication table was a notable scientific discovery, and fellows at Cambridge University and men of scientific attainments studied it. We may smile at the simplicity of our ancestors, but it is likely that posterity will smile at us, for the chemistry of many of our common avocations is at bottom as simple and as necessary as the multiplication table in the market and the counting-house.

The multiplication table not only tells us what we can do, but what we cannot do—that we can get ten dimes, but that we cannot get five quarters, for a dollar.

So also, the greatest value of science applied to an industry consists in giving a survey of the attainable ground and the means of knowing what is beyond the possibility of achievement.

The empiric experimenter is an optimist, and believes that he can accomplish much which is simply unattainable. He, therefore, loses much valuable time in futile effort. He is like a fly that butts its head against a pane of glass, never realizing that transparent media may be impassable.

If, therefore, I have led any potter here this evening to hope that with chemical aid he may attain some object he has striven for in vain, in his body, his glaze, or his fire, I must warn him also that the answer he *may* get is that he has been on a fool's errand in his quest. I have tried to show you that in this age of industrial science we have an important craft, that in progressive England and America is still plodding along without scientific aid, although chemistry picked up the most difficult of its branches a century and more ago and brought it to perfection, when the cleverest potters of Europe could not do what it accomplished, namely, the making of porcelain.

I have tried to show you why the very difficulties of pot-

ting deterred the potter from calling the chemist to his aid, even after this demonstration of his abilities, but that the chemist was also in large measure responsible for this estrangement, in that he piled up analyses upon analyses for the clay-worker's benefit, but without a knowledge of his needs and, therefore, in forms in which he could not use them.

This period is passed. The chemist has penetrated the mysteries of this black art also, and, as I have tried briefly to sketch, can lay bare the practical conditions that underlie the problems of the potter and aid him greatly in his work.

SANITARY PROBLEMS CONNECTED WITH MUNICIPAL WATER SUPPLY.*

By Prof. W. P. Mason,
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This subject is in some danger of being over-written to-day; but we have about us material evidences that it is not over-studied, especially by those boards of public officials whose responsibilities are often much greater than their knowledge of sanitary principles.

Everybody seems to be talking or writing about water, but the public is very far from being well posted upon the subject, and one encounters all sorts of odd views, which are remarkable not only for their character, but also for the tenacity with which they are held.

Occular evidence of purity is quite sufficient for most people. The bright and limpid water from a well which drains a graveyard is counted a blessing by those who would shudder at the thought of a cholera ship touching at one of our most distant ports. Nor is faith in the self-purifying power of running streams any less pronounced. The writer had the following curious criticism made of his report condemning the use of a sewage-laden river water:

"We would hint to Prof. Mason that every impurity

* A lecture delivered before the Franklin Institute, March 19, 1897.

which enters the river is either heavier or lighter than water. If it be heavier, it sinks quietly to the bottom; if it be lighter, it will remain on the surface a few hours, when it will be blown ashore by the wind.

"Water taken midway between the surface and bottom of the river will always be found as pure as the best spring water."

So long as such notions find expression in the daily press, so long, we may be sure, are the people ignorant and misinformed upon questions very nearly touching their safety, and so long there is direct need of suitable sanitary education.

It cannot be said, strictly speaking, that the adequate protection of a domestic well is a topic properly included within the limits set for us to-night; but, after all, it is upon the good sanitary conditions of the country-side that the purity of numbers of our brooks depends; and these small streams, even if not sources of town supply themselves, are tributary to the larger ones, whence the cities so often draw their water. Let it not be thought, however, that the writer would seek to protect every river in the country from all organic pollution.

Highly desirable as it would be to keep the waters of our great rivers in their natural condition of potable purity, the enormous expense of attaining to even an approximation to that state of things would be prohibitory, aside from a consideration of the great injustice to established institutions which would be caused.

Very large centers of population are already in existence, which turn their sewage directly into the river upon the banks of which they stand, and the up-stream city might well complain should it be forced, at great expense, to establish sewage-disposal plants, when the town below, for much less money, could secure a superior water from some purer inland source.

To the writer's way of thinking, a land should be looked upon as watered by its smaller lakes, its springs, and its brooks and streams, and sewered by its great, especially its navigable, rivers. Its water-sources should be protected by

law with exceeding care, and no river or stream should be added to its list of drains except after proper consideration by the State Board of Health, followed by legislative permission.

You probably recall that notable instance of the typhoid fever outbreak at Plymouth, Pa., the attending circumstances showing, as they did, the direct relation between epidemic disease and a polluted water-shed.

It will be remembered that this most serious and fatal outburst of fever was traced to a single typhoid patient, whose dejecta were thrown out upon the snow of a frozen hillside, at the base of which ran a small stream, whence the town water supply was ultimately drawn. Let it be noted that a period of weeks elapsed, during which the dejecta in question were frozen solid before the March thaws permitted the melting snows to wash them into the stream below. This failure of frost to protect against infection is but in accord with what we already know concerning the action of low temperature upon germ life. Prudden showed long ago that the typhoid bacillus can survive three months continuous freezing; while Dewar more recently found germ life to withstand exposure to the temperature of liquid oxygen (— 295° F.).

Cases such as that of Plymouth impress upon us the necessity of caring for our water-sheds and the ultimate ramifications of the tributaries to our sources of supply.

Beyond a peradventure, it is dangerous to allow human refuse material to be so disposed of as to permit of its being washed over rocky or frozen ground into neighboring brooks; and no town authority, worthy of its trust, would permit such a condition of things to obtain. But it is necessary for us to go a step farther in our precautionary measures.

Most of my hearers are probably familiar with the excellent experiments carried on at Lawrence by the Massachusetts State Board of Health, which go to show that by carefully conducted intermittent filtration through beds of sand or gravel stones, city sewage may be converted into what may practically be called potable water. Let these two very important points be always kept in mind, however:

first, the filtration must be intermittent; for if it be continuous, the atmospheric oxygen necessary to the activity of the purifying organisms of nitrification becomes excluded and purification ceases. Secondly, the dose of applied sewage must not be larger than that quantity which experiment has shown to be capable of disposal by the filter. In view of all this, what now are the conditions that we find obtaining upon many a farm and within the limits of many a town?

Human dejecta are disposed of by deposit in a vault or cesspool and the purifying power of the earth is depended upon to prevent pollution of the family well or of the adjacent stream.

Those who are acquainted with the unwise location and the filthy condition of many of the country privies must appreciate that the distance from them to the family well is often short, and that the intervening soil is required to dispose of an amount of filth greatly in excess of its powers, and that, too, by a process which must be essentially a continuous, rather than an intermittent, form of filtration.

That organic pollution of the soil is not disposed of within short distances has been definitely proven by Vaughan, who says: "I dug down a foot behind a privy vault and took up some soil 3 feet below the surface to determine the amount of organic matter in it; then I went off 6 feet and did the same thing, then 12, then 18, then 24, then 30; and, without going into detail, suffice it to say that the contamination of the soil from that single privy, built upon nearly level ground, could be detected 50 feet from the vault plainly."

The claim of typhoid fever to be a country rather than a city disease, is, for the State of New York, approximately represented by the ratio of the figures 33 to 24. The average annual typhoid death rates for thirteen Massachusetts cities stand:

Before introduction of public water supply	7·94 per 10,000
After such introduction	3·83 " "

For the whole State of Connecticut the per cent. of typhoid deaths to total deaths has fallen from about 5·8 in 1870 to 1·84 in 1893.

Such figures show the advantage of more or less carefully selected public waters over the general run of those derived from domestic wells.

We are all familiar with the ordinary country well, and we can, unfortunately, testify to the opportunity at times existing for pollution entering at its open top, but it is hard, indeed, to believe, as some would have us do, that all well infection is to be accounted for in that way.

Dr. Barwise's experience during the typhoid epidemic at South Wingfield,* in 1892, is interesting in this connection. He found that typhoid excreta, which had been carefully buried, so polluted the drainage that the infection was carried to a large number of people lower down the hill, a fact that certainly shows inefficiency of soil filtration in that instance.

So convinced has the writer become of the danger to health, arising from the unsanitary methods practised for the disposal of excreta in the country, that he has more than once attempted (unsuccessfully) to have the law direct that all such material should be subject to frequent removal, and that if buried, the place of such burial should be very often changed, so as to secure all the advantages arising from an intermittent form of sewage filtration.

The general trend of our information goes to establish the fact that proper care of the water-shed is as necessary as it is unusual, and I firmly believe that such care should be carried even to the extent of protecting the ground-water for a reasonable distance before it enters the draining brooks of the district.

After a suitable and well-protected gathering-ground has been secured, and after the water has been started on its way to the consumer, other opportunities for material pollution not infrequently arise. The larger cities of our country construct aqueducts or pipe lines which carry the water from the point of collection to that of distribution, under circumstances which preclude the introduction of sewage material, but such an arrangement is by no means univer-

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***"Disinfection and Disinfectants," Rideal, p. 150.**

sal. Open channel-ways as means of conveying water to a town are quite commonly seen, and care is not always taken that pollution shall not reach the water during its flow therein. To go back a few years, we find a very noteworthy case of contamination under just such circumstances recorded in the history of the cholera epidemic at Messina, Sicily, in 1887.

The plague lasted from September 10th to October 25th, during which time there were some 5,000 cases and 2,200 deaths. Although for a time the number of daily cases was excessive, running as high as 400, the ordinary number was about 70. The population was stampeded, falling from 71,000 to about 25,000. The government felt that a very possible cause for the rapid spread of the scourge lay in a contaminated drinking water, and an inquiry, resulting in the development of the following facts, fully confirmed the suspicion: The water as it left the gathering-grounds in the mountains was of excellent quality, but it was conveyed to the city in a conduit entirely open. Those who are familiar with European customs will remember that the washing of soiled linen is there largely an out-of-door occupation, conducted in the nearest available water-course. For the benefit of the Messina washerwoman a portion of the public water was deflected, before reaching the walls, and turned into neighboring washing-pools of stone. A fair proportion of this deflected water, after having been used for laundry purposes, found its way back into the channel, and continued its course to the city. Further contamination occurred within the town itself, for the reason that the mains of the distributing system were of unglazed tile, badly joined, and were laid in the immediate vicinity of unglazed tile sewers, also very leaky. The sewers were at times found on top of, and parallel with, the water-mains.

Acting upon its conviction as to the cause of the great mortality, the government sent tank ships to the mainland, filled them with pure "Serino" water, supplied the people therewith, and the daily number of cholera cases immediately fell from seventy to five; or, to quote an expression of the time, "the plague ceased as if by magic." An entirely

new and efficient distributive system has since been introduced, the open conduit has been replaced by modern pipe and the city has escaped further visitation by cholera.

The influence of the washerwomen in spreading cholera in Messina reminds us that the great epidemic at Cuneo, Italy, in 1884, resulting in 3,344 cases, was traced to identically the same source. Infected linen had been washed in a brook communicating with the public water supply.

Perhaps one of the most common means of fouling these open waterways depends upon the claim of some riparian owner to exercise his right to "water his stock." Most varied notions seem to dwell in the minds of sundry interested parties with reference to what the legal limits of this "watering" may be.

However much the meaning of the expression may be tortured and twisted by the experts of the bar, the ordinarily sane and disinterested layman must surely hold that the giving of drink to animals is all that the spirit of the law ever contemplated, and that no license to pollute the stream with excrementitious matter and general barnyard drainage was ever intended. Within the very recent past the writer counted no less than twenty-six cows in a pasture through which ran the open water course connecting the storage and distributing reservoirs of a city. The animals had perfect freedom to wade in the stream to within a few hundred yards of the point where the water entered the city mains.

Such public sanitation is very faulty, even upon æsthetic grounds, and outside of any question concerning the production of disease through the ingestion of fæcal material from sources other than human.

Placing our attention upon typhoid fever for the moment, it will be remembered that two conceptions of its origin are entertained by opposing schools of bacteriologists. On the one hand it is held that the typhoid germ is always the offspring of a bacillus of its own kind; while, on the other side, there are those who believe, and it is a very conceivable belief, that the progenitor in question is often a saprophyte which takes on its pathogenic properties by culti-

vation through successive generations under favorable conditions.

Many illustrations are available, in the world of larger vegetables, of great changes in structure due to cultivation under an altered environment.

Roux and Rodet are perhaps the leaders among those who claim a saprophytic ancestry for the typhoid germ, but they are not without a strong following in this country, especially among the medical officers of our army, who "look with favor on the theory of a *de novo* evolution of the typhoid fever germ from saprophytes in the soil as the only method of accounting for the occurrence of cases during field service when the troops have been operating in unsettled parts of the country for weeks before the febrile attack became manifest."*

Whatever may be the final decision of the specialists upon this knotty point, it is our manifest duty, as guardians of public health, to adopt for the present the saprophyte theory as our working formula and to protect our water supplies from infiltration of animal waste material, from whatever source, remembering that the presence of filth and the production of disease are very closely related.

As directly connected with what we have touched upon, namely the conveying of water in open channels, comes the question of the self-purification of water under such circumstances, and we are at once confronted with the strong views held thereon by the public at large. Despite the very great amount of published testimony tending to show the restricted limits within which self-purification in running streams is possible, the people have an abiding faith in the thorough efficiency of the same, and their belief in the great benefits to be derived from a short distance of open flow appears to be beyond the power of science to weaken.

Agitation and aëration do certainly aid in preventing abundant growth of algæ, with their objectionable tastes and smells; and an undoubted improvement in quality of water results from the establishment of a fountain in, or

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* Surgeon General's Report, 1896, p. 44.

otherwise blowing air into, a too quiet reservoir; but the expectations of those who hope to thus easily eliminate pollution of a serious character will not be realized.

So far as aëration is required to furnish oxygen, wherewith the nitrifying organism can do its work, it has long since been pointed out that the bacterium does not suffer any loss of its efficiency, even though the oxygen be greatly reduced in quantity below the normal supply. The presence of some oxygen is essential; but just as complete oxidation is obtained when 3 or 4 per cent. is furnished as when the full allowance is supplied.

Sedimentation plays a part in the general purification during open flow—but it is commonly a small one, particularly small in such streams as stand in especial favor with the public, because of the riffles and other interruptions in their courses.

The influence for good of the higher organic life must also be recorded, but even with this reinforcement the sum total of self-purification which occurs during the flow of a polluted stream is so insufficient as to permit of the carriage of infection for many a mile towards the sea. Instances substantiating this statement would but weary the hearers by their numbers and sameness.

To revert for a moment to a former paper of mine, read in this hall some years ago, the point was made, and I think sufficiently established, that the rate of self-purification of water varies directly as the amount of contamination; that is to say, the amount of pollution disappearing per mile of flow, stated as per cent. of the total pollution present, will be greater in a water heavily laden with sewage material than in one relatively much purer. Consequently, the rate of purification decreases as the stream flows on.

Some of the means for the self-purification of water, which we find so insufficient in running streams, do, however, arise into very respectable dimensions, indeed, when we consider the question of drawing our supply from a lake, particularly a large one. Sedimentation in such an instance becomes of prime importance, and as the element of time enters so largely into the consideration of these

cases, material changes for the better are often noticeable in lake waters; thus the tributary of a lake may be undesirable for domestic use, while its outlet may be entirely satisfactory. It is interesting to note in this connection, however, that sedimentary deposits of polluting materials should not be disturbed after settlement, for they may retain their objectionable properties long after they have separated from the water levels above them. The writer has had occasion to observe this in connection with sub-aqueous blasting; and Rafter quotes the coincidence of outbreaks of typhoid fever at both Zurich and Geneva, Switzerland, with dredging of the lake bottom and consequent stirring up of the deposited mud. In similar manner, any large and shallow lake which is subject to gales of wind, must necessarily be often stirred throughout its entire depth by violent wave action, with consequent deterioration of its waters.

Among the great lakes of North America, Lake Erie is an instance of such a condition of affairs, its depth being but 90 feet on the average, an insignificant showing when compared with its much deeper neighbors.

The relatively small lakes, of perhaps no greater depth, particularly those which are protected by neighboring mountains, furnish conditions very much more suitable for quiet sedimentation. Wave action is of course present in these lakes as well, but the depth to which it extends will rarely exceed about 20 feet, and when once the falling sediment passes below that plane there is no chance of its being raised again except through the agency of vertical currents established by variations in the water temperature.

Let us consider for a moment how such currents may be formed.

Fancy the upper water layers of a lake heated by the summer sun and consequently rendered specifically lighter than the colder bottom ones upon which they float; as the cooler autumn season approached, the surface water would gradually cool down until, towards the verge of winter, a temperature would be attained which would increase its

gravity to and beyond that of the lower layer upon which it floated.

When this point was reached, vertical circulation would be at once established, and the lake would "turn over."

With the advent of freezing weather, a second period of stratification would be inaugurated, which would continue until the surface thawed again in the spring. Vertical circulation would then progress until the warm sun of later April rendered the surface water so light as to permit of its floating upon the colder layers beneath, when summer stagnation would again begin.

All this is a matter of importance to the water consumer, because it becomes advisable to avoid, if possible, drawing the supply from the stagnant layer, if the same be resting upon a dirty bottom, for the reason that such water is of necessity heavily charged with products of organic decay. Let it not be supposed that water from such a layer is objectionable *per se;* clean water stored in clean reservoirs must form layers, of course, but the bottom portions may be used and enjoyed as freely as those nearer the surface.

When the periodical "turn-over" takes place, the water which has rested upon a dirty bottom starts upon its upward course, carrying with it and diffusing throughout the entire lake body, the accumulation of extractive materials it has gathered during its period of rest. As a result, much plant food is distributed through the upper water, where the presence of suitable light and air encourage the development of quantities of minute plants, whose growth and decay cause the unpleasant tastes and smells so often met with in our city supplies.*

Perhaps it might be of interest in this connection to refer to a suggestion recently published by one of our sanitary engineers, to the effect that the cleaning of storage ponds is all a mistake, and that it would be far better practice to leave the vegetable *débris* where nature placed it, and even

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* The relation of this growth of "diatoms" and the annual "turn-over" is very beautifully illustrated by G. C. Whipple. *Technology Quarterly,* IX, 145.

add to the vegetation rather than to diminish it. It must be replied that comparative experiments upon reservoirs have shown that improved water unquestionably follows cleaning; and it must be, moreover, remembered that, while good water may be obtained from swamp sources where vigorous growth disposes of the products of decay, yet quite the reverse obtains under conditions which permit the products of decomposition to accumulate.

In connection with this let it be said that the bottom of a proposed reservoir should, so far as possible, be cleaned of all varieties of vegetable material, and it is even desirable to also remove a portion of the upper soil, as it commonly carries quantities of organic remains. Decomposition of recently killed vegetation takes place under water quite rapidly at first, but the process is shortly converted into one of exceeding slowness, particularly where the covering water is deep. So permanent, in fact, is timber which has been deeply submerged, that the oaken piles, which, in prehistoric times, supported the buildings of the Swiss "lake dwellers" are still firm and solid, although black in color. Alternate flooding and exposure to sun and air is quickly destructive of vegetable matter, and, as a result, a reservoir with very gently sloping sides furnishes conditions favorable to a contaminated water supply, particularly if it be liable at times to considerable reduction in depth of water. Even though the level of its contents be always maintained at high-water mark, sloping sides would permit thin layers of water to be overheated by the summer sun, thus encouraging abundant growth of aquatic plants, which subsequently decay, to the damage of the water.

It is especially undesirable to permit the bottom of a storage-reservoir to remain exposed for more than one season, for the reason that vegetation will develop in such quantity as to greatly damage the water when the bare slopes are again submerged.

Owing to experience already obtained in such matters, the Boston authorities propose to remove the soil from the site of the new Nashua reservoir (about 7 square miles of area), at a cost of $2,909,000. "In order to deter-

mine the amount of soil to be removed, a number of test-pits were dug in representative localities to a depth of 3 feet, and from the sides of these pits samples of the soil were carefully collected at different depths. Analyses demonstrated that the amount of organic matter in the ground was generally so small below the layer of black loam that it would be necessary to remove only this layer." Some 800 holes were dug to determine the average depth of this layer, and it was concluded to remove 9 inches from the wooded portions, and 11½ inches from the cleared lands.*

No stripping of the soil from the bottom of the Vyrnwy reservoir, supplying Liverpool, was done, but the water is filtered before delivery for consumption. Filtration is so common in Europe that the same care in storage is not so necessary as it is in this country, where the practice is to pipe the raw water direct to the consumer.

As an instance, showing the necessity of thorough removal of the upper soil-layer from a proposed reservoir site if bad odors are to be avoided, the very recent experience with Reservoir M of the New York Croton water system is a case in point.

So obtrusively penetrant did the odor become that many folk, believing the water to be infected, closed up the wells from which they procure their drinking-water, and some were even forced to abandon the hamlet as a residence until the atmosphere regained its purity and pleasant odor.

The reservoir was built on condemned land, on which formerly were gardens, orchards and dwelling houses, and through which meandered a small stream known as the Titicus. The 1,000 acres of land covered by the reservoir were cleared of everything excepting the growth of grass, which was left in most cases intact, or at least was not ploughed.

For such as may not be familiar with the exceeding foul smell fresh green grass will give if steeped in water it might be interesting to try the experiment upon a small

* Massachusetts Board of Health, 1895.

scale by covering some with water in a bottle, and allowing it to stand a few days.

Depth of reservoirs is not so important as the presence of food-supply in the matter of the existence or absence of organisms. The Massachusetts Board of Health reports the case of Pilling's Pond, a very old storage-reservoir, 85 acres in surface, with an average depth of only 3 feet. No abnormal growths appeared in this reservoir, nor did the water become offensive, although its temperature at times reached 80° F. The explanation offered is that, owing to the age of the reservoir, the bottom mud no longer contains food-supply.*

Sulphuretted hydrogen frequently adds its disagreeable smell to the offensive odors occurring in new reservoirs, particularly shallow ones. The decomposition of vegetable material, killed by flooding, causes a reduction of the sulphates present to sulphides, and these sulphides are further acted upon by the acids, also formed by such decomposition, with liberation of the foul-smelling gas. The author found this gas on one occasion due to a somewhat unusual cause. The reservoir-dam had been built of blast-furnace cinder, and the water was in consequence, strongly impregnated from the sulphur compounds contained therein.

Waters from underground sources should be distributed for use as soon as possible after they have been brought to the surface; for they are commonly well supplied with plant-food in solution, and, under the influence of light and air, there is danger of abundant development of objectionable algæ if much time for open storage be allowed.

With surface-waters the case is quite the reverse, and long storage becomes a distinct advantage if the reservoir be clean.

Sedimentation of suspended impurities, and destruction of bacteria by simple lapse of time, are two sources of benefit arising from impounding of surface-water.

Bacteria often die but slowly, and although a large percentage of their number will disappear through storage, it

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* Massachusetts Board of Health, 1890, **1**, 749.

should not be forgotten that they are very small and very light, and consequently are very long in settling; so that it should not be expected that a reservoir could do the efficient work accomplished by a filter.

Percy Frankland found the following numbers of bacteria per cubic centimeter in Thames water at the intake of the Grand Junction Company, and in water from the large reservoir of the company, where the greater part of it had been stored for six months, and none for less than one month:

	Bacteria.
Intake	1,991
Reservoir	368

The value of sedimentation was shown at Philadelphia during the prevalence of typhoid fever in that city in 1891. "By much the highest mortality is in the Twenty-ninth and Thirty-second Wards. This is an elevated section of the city, newly improved and occupied for the most part by well-to-do people. The drainage is good and the laws of health are doubtless as well observed as in any other portion of the city. But these wards are too high to draw water from the subsiding reservoir, and they are accordingly furnished by direct pumpage from the river. This is the case also in the Twenty-eighth Ward adjoining, and the district so supplied extends southward including the Fifteenth Ward, another well-to-do part of the city, where typhoid is especially prevalent. These four wards, furnished by direct pumpage, have a population of 184,000, and report 317 cases of typhoid fever, or at the rate of 172 to 100,000 inhabitants."

The West Middlesex Company causes its water to pass through two storage-reservoirs before it is delivered upon the filter-beds. The influence of such passage is seen in the following counts of bacteria as made by Frankland:

	Per c.c.
Intake at Hampton	1,437
After passing first reservoir	318
" " second "	177

The influence of precipitating mud in hastening the fall

of bacteria was investigated by Krüger.* By the use of ½ gramme of fine sterilized potter's clay per liter of water he obtained the following counts of bacteria per cubic centimeter of water. The temperature was maintained at 55° F.

	Water with Clay.			Control Water Containing No Clay.		
	Top.	Middle.	Bottom.	Top.	Middle.	Bottom.
After standing 2 hours	575	887	33,495	5,340	6,110	5,480
" " 20 "	521	155	43,595	5,960	6,710	6,210
" " 50 "	6,933	6,190	66,350	7,230	5,987	6,924

This action was to have been expected, in view of the well-known tendency of falling solids to drag down other matters with them, even at times when such other bodies are in solution. Bacteria, being in suspension, are more readily influenced by the depositing silt.

Having once entered the city mains, there is yet possibility of local contamination reaching a water, as we have seen was the case at Messina, Sicily. The ancient town of Pisa, at a recent date, also presented a similar instance of contamination from leaky mains lying near broken sewers, although the thorough change that has been made in the distributive system of that city has remedied all that difficulty. In our own day and generation such accidents are not unknown; and it has chanced that on two occasions the writer has seen water pipes in direct contact with sewage, and, in one instance, the main of a large city street actually cut through the sewer.

Fears are allayed in such cases by the argument that the pressure of the water in the pipe would surely cause a flow outward, not inward, in the event of rupture; but when one calls to mind the familiar laboratory device known as the "Richards pump," which depends for its action upon the power of the rapidly moving water to suck air in at the open side tube, one feels that circumstances might so obtain as to permit of the "Richards pump" principle coming into play,

* *Zeit. f. Hygiene*, **7**, 86.

and should such an accident happen, the results would be most unsatisfactory.

From whatever source the water may be derived, it is the common American practice to deliver it "raw" to the consumer, even when its appearance is distinctly unsightly. Such is not the European custom. Public sentiment abroad demands that surface waters should receive efficient purification before they are distributed for domestic use, and in Germany such purification is regulated by statutory law. As a result, filters are established or arrangements are contemplated for their erection to filter waters of a degree of natural purity equal to the best supplies America can show. We, on this side of the Atlantic, would consider the expenditure of money for the purpose of purifying such waters as we find at Zurich and Liverpool, quite unnecessary and superfluous. Europeans think differently, however, and their notions are best expressed by Voltaire's apothegm: *Le superflu—chose tres necessaire.* It is very amusing to note the care with which Americans, perhaps from Albany, Pittsburg or Chicago, scrutinize the water offered them in foreign capitals, when what they are in the habit of drinking at home would not be tolerated for an instant in the great cities of Europe.

The day is past when we could feel a sense of superiority over the crowded millions of the old world, because of the relative magnitude and consequent initial purity of the sources of our water supplies. Europe has, of late years, expended much labor and capital in substantial plants that make for sanitary betterments, while we have continued upon a conservative course, forgetful that our populations and industries have been growing, and that the river our fathers drank from with pleasure and safety has become charged with the refuse of up-stream communities, and converted into what may be properly styled the county sewer.

These improvements for the betterment of water, into which Europe has gone so largely and from which we so uniformly shrink, cost much money. Do they pay?

To abandon an existing water supply system or to purify the polluted water that it furnishes, always involves the

outlay of much money, and the city taxpayer has the right to inquire whether or not the benefit derived is a fair equivalent for the cash expended. Impure water affects the yearly death-rate, as a whole, much less than that section of it which deals with diseases recognized as "water-borne," prominent among which is typhoid fever. No better measure can be selected of the wholesomeness of a city supply than that furnished by a list of the annual cases of this serious disease.

Typhoid fever is doubtless, to a very large extent, a preventable disease, but the means of prevention, in the shape of great public works, are expensive, and again the question is asked, do these works pay? Can we afford to save the typhoid victims?

According to Rochard, the economic value of an individual "is what he has cost his family, the community, or the State for his living, development and education. It is the loan which the individual has made from the social capital in order to reach the age when he can restore it by his labor."

The statement of this value, in form of money, is a difficult matter, which has been variously settled by sundry investigators. Chadwick considers an English laborer equivalent to a permanent deposit of £200 (say $980). Farr gives £159 (say $780) as the average value of each human life in England. A French soldier is rated as worth 6,000 francs (say $1,200).

In view of the fact that typhoid fever selects by far the greatest number of its victims from among those in the very prime of life, to the relative exclusion of the very young and the very old, it will be reasonable to follow the figure fixed upon by E. F. Smith, and place the loss caused the community by a death from typhoid at $2,000. This will be noticed to be less than half the figure so frequently referred to in the courts of the State of New York for the value of a human life.

From the statistics issued by the health office, it appears that the annual average number of deaths from typhoid fever, which occurred in the city of Philadelphia during the five years 1890 to 1894, inclusive, was 523.

Rating the money value of each life at the figure given above, this death-rate would mean an annual pecuniary loss to the city of $1,046,000.

Funeral expenses are variously estimated at from $20 to $30. Should we accept the intermediate value of $25, this item would cause $13,075 to be added to the above sum, thus raising the total direct loss through death to $1,059,075.

But typhoid fever does not always kill. Its mortality rate is commonly quoted at about ten per cent. For the present purpose, should we assume nine recoveries for each death from the disease, and place 43 days as the period of convalescence (the average of 500 cases at the Pennsylvania Hospital), we should have a term of 202,401 days as representing the time lost, per year, by the 4,707 persons who have the fever and recover. Thus an annual loss of over 554 years has to be borne by the city's capital of productive labor.

This great amount of enforced idleness, when translated into money value, should very properly be added to the death loss above estimated.

Fixing the rate of wages at $1 per individual per day—a very low figure, considering that the bulk of typhoid patients are in the very prime of life—there is a loss of $43 of wages for each recovery, or a total yearly loss for the city from this item of $202,401. The cost of nursing and doctors' bills equal at least $25 per case, which is a very low estimate, thus adding the further amount of $117,675 to the gross sum.

Expressed in tabular form, this yearly tax imposed by typhoid fever upon the citizens of Philadelphia would stand:

523 deaths, at $2,000 each	$1,046,000
523 funerals, at $25.00 each	13,075
Wages of 4,707 convalescents during 43 days, at $1.00 per day	202,401
Nursing and doctors' bills for 5,230 cases, at $25.00 per case	130,750
Total annual tax levied by typhoid fever upon the city of Philadelphia	$1,392,226

Public works which could eliminate a reasonable fraction of this great tax would certainly pay for themselves in the

course of a few years, even though they were originally expensive.

This is not the place to discuss the advantages of various filtration schemes, first because it would take us far beyond our reasonable limits, and, further, because your engineers have covered or are about to cover all such questions so far as they apply to the special wants of your city; but let me leave this one additional thought with you, using the statistics as given above.

Suppose some public undertaking (the much-accused trolley system, for instance) were so badly managed that 523 human lives were crushed out annually and some 4,707 other persons were more or less seriously injured, do you suppose that the good people of Philadelphia would tolerate such a state of affairs, or that they would grudge the amount of money necessary to stop such carriage? Surely not; yet they are submitting quietly to just as large a loss from death and disability, only it comes in a way less tangible and less shocking to the feelings.

There is, believe me, no system of filtration, or other efficient method for purifying a polluted water, so expensive but that a community can well afford to introduce it rather than to drink a dangerous water in its raw state, and this, too, from purely economic considerations, and leaving out of sight all ethical questions whatsoever.

Without wishing to "thrash old straw," let me ask such as may have doubts upon this point to read again the history of the epidemic of typhoid fever in the valley of the Tees, and the records of the late cholera plague at Hamburg, and to note what such dire experiences have taught and what use has been made of the teaching.

Finally, let us inquire, do those interested in the furnishing of water to a town ever permit a factor to enter their calculations representing the pecuniary damages that might be claimed by parties who receive bodily injury through the use of impure water? This question appears to be assuming some magnitude just at present, and if the courts look favorably upon it, there is scarcely a limit to the proportions it might assume. Sundry suits are now pending in the West

to recover the legal value of human life alleged to have been destroyed by typhoid fever, contracted by the use of impure water. Such suits are based upon evidence tending to show that the public waters in question are seriously polluted by sewage, and are consequently sources of disease.

Fancy, if you will, what a disturbance would ensue in water circles should these plaintiffs gain their causes. Precedents would be established that might well carry financial ruin to many a corporation, whether public or private, and figures of such size for damages would be added to those representing yearly loss already given, as would make the most conservative member of the Board of Water Commissioners admit very candidly that cheap water may be at times a poor investment.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, March 17, 1897.

JOHN BIRKINBINE, President, in the chair.

IMPROVED SAFETY DEVICE FOR ELECTRIC CIRCUITS.

BY LEWIS G. ROWAND.

The demand for some means of protection against the dangers that arise from the accidental breaking and grounding of heavily charged overhead wires, has brought forth various devices to accomplish this end.

My method of reducing the element of danger arising from this source is to open the circuit at the instant the wire breaks or becomes short-circuited.

While this principle can be used on any electric circuit, it is particularly well adapted on electric railroad circuits, and it is in connection with this line of work that I have prepared an exhibit which will enable me to give you a practical illustration of its application.

I will show, by aid of certain models and drawings, different applications of my device to meet the various requirements of electric trolley circuits.

In order to make the following explanation as comprehensive as possible, I have prepared drawings of each model, having all parts lettered, to correspond with such parts shown thereon.

In the drawings, *Fig. 1* is a diagram of a single line, and of the wiring of Board No. 1.

Fig. 2 is a diagram of a single line, and of the wiring of Board No. 2.

Fig. 3 is a diagram of a double line, and of the wiring of Board No. 3.

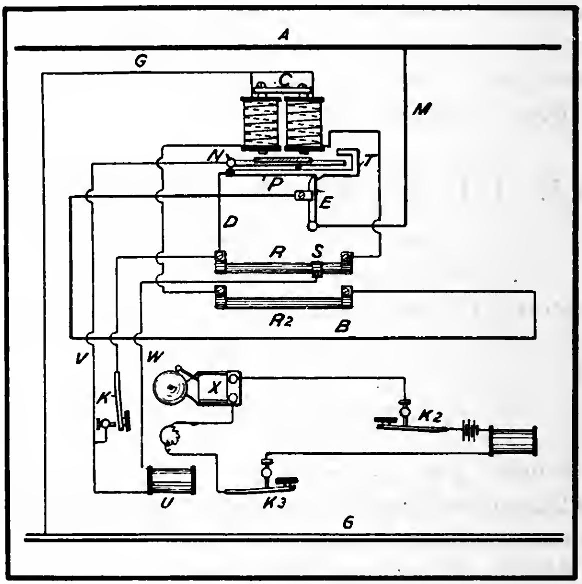

FIG. 1.—Diagram showing single section with alarm circuit.

Fig. 4 is a diagram of two sections of a single line and of the wiring of Board No. 4.

Referring to *Fig. 1* and Board No. 1, *A* is the main feed, or trunk wire, *B* the trolley section. The return of this trolley section, *B*, before passing to ground, passes through the resistance, R^2, and the electro-magnet, *C*, which has double windings, the winding being such that when current passes through both windings, one neutralizes the other and consequently there is no magnetic result, and the magnet is not energized. The trolley section, *B*, passes to one

of these windings; a wire, *G*, is connected to rail; *D* is a wire, connected also with the trunk line through switch contact and to the other winding of the magnet, *C*, the trolley section, *B*, and wire, *D*, having a common connection with the trunk line, *A*, through wire, *M*. The wire, *D*, is connected, through resistance, *R*, with the opposite winding of the magnet, *C*, of that to which wire *B* is connected. Thus it will be seen that the circuits formed by wire, *B*, and wire, *D*, have a common connection with the trunk line, *A*, through wire, *M*, with the source of current supply (trunk, *A*), common to both, each circuit having a winding of the magnet, *C*, in circuit; but the windings are such that when current passes through both windings, the two circuits neutralize each other, and the magnet is not energized. Upon the connection, *M*, common to both circuits, *B* and *D* is switch, *E*, which switch is normally closed and is controlled by armature, *N*, of the magnet, *C*.

It is desirable that the least possible amount of current should pass to the magnet, *C*, through the currents, *B* and *D*. This is accomplished by making the resistances *R* and R^2 very high, as is here shown. At 220 volts, we have, in circuit *B*, 3,000 ohms, taking ·073 ampère. In circuit *D*, we have also 3,000 ohms, taking ·073 ampère. Combined resistance 1,500 ohms; total, ·146 ampère; or 32·12 watts consumed at each switch.

Under these conditions, when the magnet becomes energized it is but slightly so, and therefore would not be strong enough to trip the switch, which must, necessarily, have a powerful spring to ensure opening the switch quickly. I, therefore, provide the following lever, *P*, instead of being acted upon direct, through the medium of pivoted lever, *N*, which forms the armature of the magnet, *C*. The lever, *P*, has a projection, *T*, in the line of movement of one end of lever, *N*. Both levers, at this point, carry contact points normally out of contact with each other. A wire from one side of resistance, *R*, in circuit, *D*, passes to lever, *P*, and from sliding contact, *S*, on resistance, *R*, a wire passes to lever, *N*, through signal magnet, *U*.

Now suppose the circuit, *B*, to become broken. First, the

magnet, *C*, is energized by the slight amount of current in circuit, *D*, passing through resistance, *R*, which is enough to attract the armature, *N*, so that the contact on it, and that of lever, *P*, are brought together, thus allowing the current in circuit, *D*, to pass to the magnet, *C*, through wire, *V*, through magnet, *U*, through wire, *W*, to sliding contact, *S*, through a portion of resistance, *R* (which can be adjusted to the necessary amount of current required to operate the switch), through wire, *D*, drawing up lever, *N*, so that it, acting on the projection, *T*, of lever, *N*, draws up the lever which trips the catch, allowing switch, *E*, to open the circuit. At the same time, the current passing through magnet, *U*, of the signal device releases the mechanism and signals the number of the box (which is in this case No. 87) to the station or repair wagon, or both. This signal passes over an independent circuit, preferably a closed metallic circuit, such as is used for fire-alarm. We can, by using key, K^3, signal to Station, also receive signals from Station on gong, *X*.

If repair wagon should be at box No. 87 when another switch on the same signal circuit opens, the men would hear the number of the switch thus opened tapped on the gong, and could go directly to the point without returning to the Station. If the presence of the repair-men were required to answer a signal received from another circuit at Station, while attending to a previous call, they may be notified of the last call from Station by giving the required number of taps over the circuit on which they are at work. The signal movement can also be started by hand without the opening of the switch. A telephone connection can be made in each box, permitting conversation between each box and Station. There is also included in each box a signal key, *K*, which is a very important feature of the system. In the event of a fire, the policeman, fireman or trolley employee can, by opening the signal-box and pressing key, *K*, open the switch and notify Station at the same time. The wire in that section is then dead and the firemen need lose no time in getting at work. After the fire, there will be no delay in repairing the line, as there are no cut wires

to splice. All that is necessary is to close the switch and the line is ready for the cars.

In *Fig. 2* and Board No. 2, the arrangement of switch and

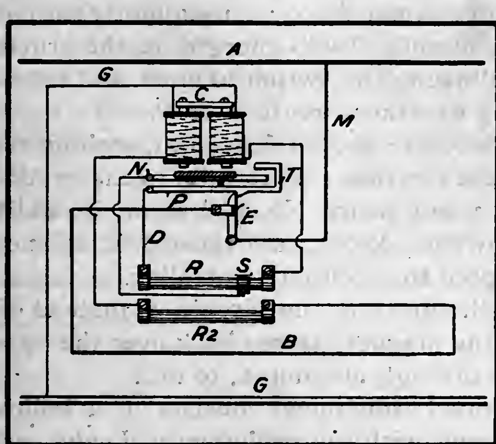

FIG. 2.—Diagram showing single section.

circuits are identical with that of No. 1, which I have just described, except that the signal device is omitted.

The practical operation of this switch may be thus

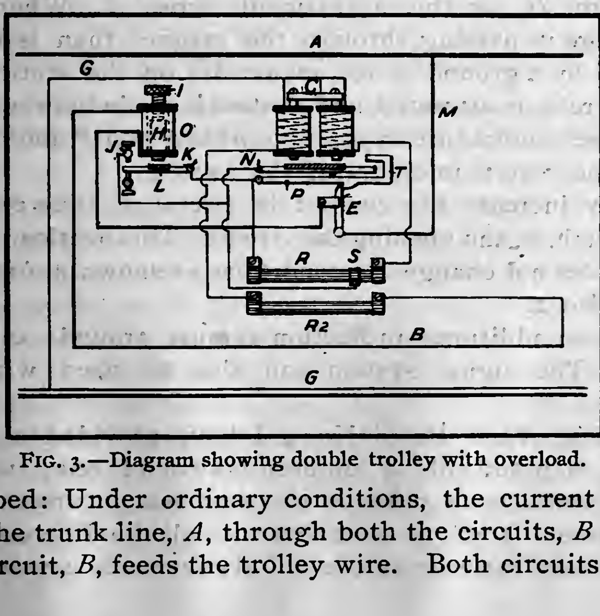

FIG. 3.—Diagram showing double trolley with overload.

described: Under ordinary conditions, the current passes from the trunk line, *A*, through both the circuits, *B* and *D*. The circuit, *B*, feeds the trolley wire. Both circuits, *B* and

D, pass through the magnet, *C*, but in such directions as not to energize it. Now, if the trolley wire, *B*, should break, the current will no longer, as far as that circuit is concerned, pass through the magnet, *C*; consequently the currents passing through circuit, *D*, will energize it, the armature will be attracted, allowing the switch to open, and cut off any current passing to either circuit, *B* or *D*.

The trolley wire is then dead, and, without regard to the number of cars in that circuit, falls to the ground harmless.

In *Fig. 3* and Board No. 3 I show, in addition to the devices shown in No. 2, an overload attachment and the switch adapted to a double line trolley.

In this illustration, the circuit, *B*, instead of returning directly to the magnet, passes back over the opposite track, and thence through magnet, *C*, to rail.

The overload attachment consists of a hollow spool, *O*, wound in series with the trolley wire, *B*, and carries all the current passing to the trolley wire. I have provided means whereby the switch may be adjusted to carry any desired ampèrage. *H* is a sliding core, fastened to an adjustment screw, *I*. The adjustment is reached by raising or lowering the core, *H*, by the adjustment screw, *I*. When more ampèrage is passing through the magnet than is desired (caused by a ground or too many cars on the section), the armature, *L*, is attracted, and contact is made between *J* and *K*; these contacts are in multiple with *N* and *P*, and produce the same results in operating the switch.

They increase the current in circuit, *D*, thus releasing the switch, *E*, and opening the circuit. This overload attachment does not change the conditions as shown in *Fig. 2* and Board No. 2.

It is an additional protection against grounds and overloads. The signal system can also be used with this device.

In *Fig. 4* and Board No. 4, I have provided a switch which is practically a differential-wound relay, to have special contacts in practice to carry heavy currents for a short time. It will be seen that with all the different relay devices used in these switches, I always *make* contacts and

do not *break* them. The current is always thrown off at the switch.

This relay has two windings, the same as in the switches heretofore described; one winding being in one trolley section, the other in the other trolley section. The breaking of either one of the trolley sections will operate the relay, which throws a ground on the main feed wire, *A*, which will cause the overload switch at the station to open.

(This device can also have the signal attachment, but not the overload device.)

With this arrangement a trolley road would require but

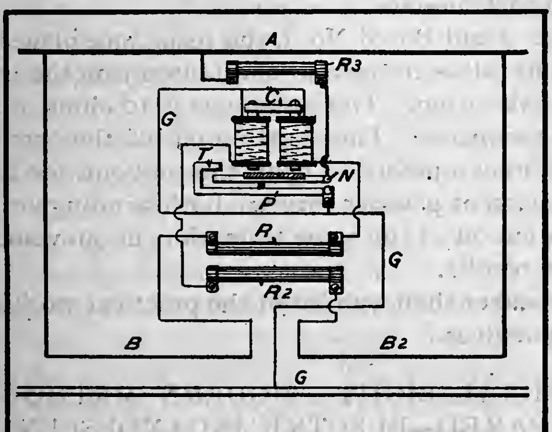

FIG. 4.—Diagram showing two sections, overload switch at Station for economy.

one-half the number of switches, as one switch will operate two sections. But the disadvantages would be that the operating of one switch would cut off the current from the entire circuit. *A*, the main feed or trunk wire, passes through overload switch, *O*, at Station; *B* and B^2 are trolley sections, the returns of which pass through the resistances, *R* and R^2, to the differential magnet, *C*. *G* is connected to rail or return. Now, suppose the circuit, *B*, to be broken, the current will then cease to flow through winding, *B*, of the magnet, *C*, and the magnet will be energized by the current passing through circuit, B^2. This will attract armature, *N*, and make contact, *T*, and close circuit with con-

tact, *P*, through wire, *G*, to rail through resistance, R^3. (This resistance is used for this special occasion to prevent short-circuiting the mains.)

This resistance is 12 ohms at 220 volts, giving $18\frac{1}{3}$ ampères. This operation will throw the overload switch, *O*, at the Station and open the entire circuit. In the event of circuit, B^2, becoming broken, the action is exactly the same.

This device will reset itself after throwing the overload switch at Station.

The cut-outs and devices exhibited here to-night were built for experimental purposes, and are not calculated for standard instruments.

In *Fig. 3* and Board No. 3, the resistance placed between trolley and rail is to prevent short-circuiting the mains during this exhibition. The resistance is 10 ohms at 220 volts, giving 22 ampères. The shutting off of the current at the station cannot operate to open this cut-out, for the reason that the current passing through both windings of magnet, *C*, will be cut off at the same time, thus no movement of the armature results.

[The speaker then exhibited the practical working of the different devices.]

ARTIFICIAL LIGHT: MODERN METHODS COMPARED—ELECTRIC-INCANDESCENT, WELSBACH, ACETYLENE.*

BY PROF. D. S. JACOBUS,
Stevens Institute of Technology, Hoboken, N. J.

[The lecture was introduced by experiments to show the appearance of various colors when viewed by the different lights. Two surfaces of the same color were held up at an angle between two sets of lights, each set containing eight lamps or burners. The two sets of lights to be compared were placed at a distance of about 6 feet from each other on the lecture table. Screens were placed in front of the burners, to shield the eyes of the audience

* A lecture delivered before the Franklin Institute, March 12, 1897.

from the direct glare of the lamps. In the space between the lamps colors were shown on large pieces of cardboard, doubled over at the middle so that the two sides could be held at an angle to each other. This allowed one surface to be illuminated by one set of lamps, and one by the other. The audience could observe each surface at the same time, and thus compare the colors as they appeared to the eye.

A second series of experiments consisted in viewing colors of a slightly different hue, which appeared of nearly the same hue when held in one position between two sets of lamps, and of a widely different hue when the colors were reversed so as to be lighted by the opposite set of lamps.

Many colors appeared of a different shade when viewed by the acetylene and by the Welsbach lights. Some of the colors appeared brighter under the acetylene light than under the Welsbach, and this is especially so in the case of the lighter shades of pink, whereas the reverse holds true of some other colors. On holding the hand between the Welsbach and acetylene burners, the side of the hand illuminated by the Welsbach light appeared to be of a yellowish hue, and that illuminated by the acetylene exhibited the natural pink tint. The acetylene, therefore, made the hand appear more lifelike than the Welsbach light.

Ordinary gas, and the incandescent electric light also produced more lifelike tints when the experiment was made of holding the hand between them and a Welsbach lamp.

Experiments were described, which had been made before the lecture, in which the apparent tints, when viewed by the different lights, were compared with the tints when the colors were viewed by daylight. The acetylene flame was found to show the light pinks or flesh colors much more nearly in their natural tints, or their colors when viewed by daylight, than the Welsbach. The same results followed for incandescent electric light and ordinary gas, when burned in a flat flame, both of which brought out the lighter shades of pink more truly than the Welsbach. The experiments demonstrated that there is

a very slight difference in favor of the acetylene over the incandescent light in bringing out delicate shades of pink, and that ordinary gas burned in a flat flame burner comes next in this respect.

Some colors other than pink were found to appear more nearly of their true tints under the Welsbach than under the other lights, in the experiments where the lights were compared directly to daylight.]

CANDLE-POWER DEVELOPED PER CUBIC FOOT OF GAS. ELECTRICAL ENERGY TO PRODUCE THE ELECTRIC LIGHT AND PROPORTION OF TOTAL ENERGY TRANSFORMED INTO LIGHT. ALSO, RELATIVE HEATING AND CONTAMINATION OF THE ATMOSPHERE BY CARBONIC ACID FOR EQUAL CANDLE-POWERS.

The figures for the various methods of illumination are given in Table I, in order that they may readily be compared.

TABLE I.

Kind of Light.		Candle-power of Gas on the 5 Cubic Feet per Hour Basis.	Gas Required per Hour for 16 Candle-Power in Cubic Feet.	Heat of Combustion of Gas in B.T.U. per Cubic Foot at 60° F.	Total Heat in B.T.U. for 16 Candle-Power per Hour.	Percentage of Total Heat Converted into Light.	Cubic Feet of CO_2 Produced by a 16 Candle-Power Light per Hour.
1		2	3	4	5	6	7
Illuminative Water Gas.	Flat flame burner . . .	20	4·00	700	2,800	0·6	3·4
	Welsbach . . .	70	1·14	700	798	1·9	1·0
Acetylene		200	0·40	1,420	568	2·7	0·8
Incandescent electric		—	—	—	250	6·2	0·0

It will be seen, from the figures given in Table I, that acetylene gives ten times as much light as ordinary illuminating water gas when the latter is burned in a flat flame burner, and about three times as much when the latter is burned in a Welsbach burner.

The percentage of the total heat of combustion of the gas

transformed into light is also greater for the acetylene than for the ordinary illuminating gas. For a given illumination the atmosphere is vitiated by the carbonic acid formed in burning the acetylene to a slightly less extent than when burning the ordinary illuminating gas in a Welsbach burner.

The figure for the candle-power of the gas on the basis of 5 cubic feet burned per hour, given in Table I, is from my own experiments. The figure for the Welsbach is derived from the results obtained in tests of both old and new mantles on the latest form of lamp, and is safe for ordinary practice, as it is nearer to that obtained with old mantles than to the results obtained with the new.

The candle-power given in the table is an average of the candle-power in a horizontal plane passing through the lamp center. The spherical candle-power is less than the candle-power so measured, but the proportion between the spherical candle-powers would be about the same as the proportion between the candle-powers measured in a horizontal plane, or within the range of variation of the experimental results; so that comparative figures may be obtained by using the latter.

SAFETY. EXPLOSIVE PROPERTIES OF ACETYLENE.

If 3 per cent. of acetylene be mixed with air, an explosive mixture is produced. In the case of hydrogen 5 per cent. is required, and for coal gas 8 per cent. The maximum amount of acetylene that can be mixed with air to form an explosive mixture is 82 per cent., and the corresponding figure for hydrogen is 72 per cent.

It, therefore, appears that acetylene is more explosive than either hydrogen or coal gas. As the burners used for acetylene would discharge a less amount of gas—say one-fifth that of an ordinary gas burner—the accidental opening of a burner would cause the atmosphere of the room, as a whole, to be much less contaminated in a given time than with coal gas. On the other hand, acetylene gas is so much more nearly of the density of air than ordinary illuminating gas, that it will not be diffused as rapidly through the air

in case of leakage, and will have a greater tendency to collect in a partly enclosed space, and thus cause an explosion in case the gas were ignited.

[Experiments were made in which acetylene and ordinary illuminating gas were exploded when mingled with air. The gas was allowed to escape from a burner into a tube placed at an angle. The explosion produced by the acetylene was much more severe than that produced by the illuminating gas.]

In regard to the explosive properties of acetylene itself, much may be said. When carbon and hydrogen unite to form the compound called acetylene, heat is absorbed. According to Berthelot, if gaseous acetylene, under a pressure of about 15 pounds above the atmosphere, or over, be ignited by a spark, or by a heated platinum wire, it will decompose explosively without the presence of air. The explosion becomes more violent as the initial pressure is increased. In exploding, the carbon and hydrogen are dissociated, and the heat absorbed in the original formation is set free. This heat, according to Berthelot, is sufficient to increase the temperature (provided the pressure be kept constant), about 5,000 degrees Fahrenheit, or to increase the pressure to eleven times the initial (if the volume be maintained constant). At atmosphere pressure, however, Berthelot found that acetylene gas containing no air could not be exploded; for if a spark were generated in it, or even if fulminate were exploded in it, there would be no decomposition into the elements of carbon and hydrogen, except near the point where the spark, or fulminate, acted on the gas.

Berthelot also found that liquid acetylene, as transported in tanks under pressure, would explode as readily as the gas. In one case, he exploded liquid acetylene in an iron tank by means of fulminate of mercury, and shattered the tank to pieces. He also made experiments to determine if blows or shocks would start explosions in cylinders of the liquid. He found that a shock would not of itself start an explosion, but that when steel cylinders of the liquid acetylene were smashed, the blow was usually followed by an explosion,

probably produced by the sparks generated by the friction of the pieces of broken steel. He states that local elevation of temperature may produce compounds evolving heat, and finally cause an explosion; and also that the sudden opening of a stop-cock may produce local heating and an explosion.

The investigations of Berthelot on the explosive properties of acetylene show how dangerous the gas is when stored under pressures higher than that of the atmosphere. That such is the case is borne out by the fact that a number of accidents have occurred where it has been used under such conditions.

In the Pictet works, in Paris, acetylene is compressed in steel cylinders that have previously been tested to 250 atmospheres. A short time ago a cylinder of this description, of large capacity, exploded at the Pictet works, killing two workmen and injuring another. The two men were torn to pieces, and a part of the works was blown down.

There is another case on record where a cylinder of acetylene, fitted up to light a dwelling-house, exploded and seriously injured a tinman and his laborer, who were at work upon the premises.

An explosion of liquid acetylene, resulting in the death of four persons, took place in a Berlin suburb some time in last December. This explosion occurred at the time when a chemist named Isaac, who had for some time experimented with acetylene with a view of depriving it of its dangerous qualities, was preparing an exhibition of the results of his experiments, a record of which was to be presented to the German Emperor. The use of acetylene is prohibited in Germany, owing to its explosive character, and it was to deprive it of its dangerous qualities that Mr. Isaac made his experiments, and thereby met his death.

By an explosion of a cylinder of liquid acetylene at New Haven, in January, 1896, three persons were killed and four injured. The explosion occurred while experiments were being made on a regulator to reduce the pressure in the tanks to that required at the burners.

An explosion occurred in Jersey City about one year ago,

when it was attempted to generate the gas from the carbide under pressure. This shattered the roof of the building, the apparatus being in the upper story, and demolished the woodwork in the neighborhood of the generator; but fortunately no one was near enough to the generator at the time of the explosion to be seriously injured.

All the above explosions are cases in which the acetylene was under pressure, and exploded in the same way as ordinary dynamite or gunpowder; that is, by the decomposition of its own elements without the aid of the oxygen of the air. There have been accidents, however, where it is probable that the explosions were caused by the mixture of air with the acetylene.

For example, an accident took place at Lyons a few months ago, in a café lighted by acetylene generated on the premises. The explosion produced much damage, and killed two persons.

Another explosion, or, perhaps, it might be called a case of accidental ignition of the gas, occurred in Jersey City last January. The liquid acetylene was being blown from a tank into a felt bag, in order to obtain solidified acetylene, or snow, in the same way that snow may be obtained from carbonic acid. An explosion of the escaping gas occurred, which set fire to the mass of solidified acetylene. One of the workmen was severely burned about the face and hands.

In view of the above practical demonstration of the danger of acetylene gas under pressure, it would seem unwise to use it in that way; and even when generated on the premises at atmospheric pressure great precautions should be employed to prevent explosion, on account of the admixture of air.

RELATIVE COSTS FOR EQUAL ILLUMINATION.

The costs per hour for a production of 16 candle-power of light, in the city of New York, are shown in Table II:

TABLE II.

		Cents.
Incandescent electric light at 1 per cent. per lamp hour		1·0
Illuminating water gas.	Ordinary burner, 4 cubic feet, at $1.25 per 1,000 cubic feet	0·5
	Welsbach burner, 1·14 cubic feet at $1.25 per 1,000 cubic feet	0·17
Acetylene employed for Municipal distribution.	Calcium carbide, furnished to gas company and converted into gas for $40 per ton*	0·5
	Calcium carbide, furnished to gas company and converted into gas for $19.50 per ton†	0·17

* To replace flat-flame burners.

† To replace Welsbach, cost of replacing mantles of Welsbach lamps included in the estimate.

The price at which calcium carbide would have to be furnished for domestic lighting, to be as economical as kerosene oil at 8 cents per gallon, is $45 per ton. The compressed liquid acetylene would have to be furnished for 6½ cents per pound to be as economical as kerosene.

It will be seen from Table II that to compete with an ordinary illuminating water gas selling at $1.25 per 1,000 feet in municipal distribution, the carbide would have to be furnished to the gas company and converted into gas for $40 per ton, to net the gas company the same profit, and to be as economical to the consumer as the ordinary illuminating gas burned in the flat-flame burner. To be as economical to the consumers as ordinary gas burned in Welsbach burners, it would have to be furnished to the gas companies and converted into gas for $19.50 per ton.

It is further shown that, to be as cheap as kerosene in domestic lighting the carbide would have to be supplied to the consumer at $45 per ton, and the compressed liquid acetylene would have to be supplied at 6½ cents per pound.

The figure for the Welsbach burner in Table II is obtained by adding to the cost of the gas 0·03 cents per hour per 16 candle-power to replace mantles, which are assumed to cost 50 cents, and last 500 hours on a lamp furnishing 50 candle-power. The difference in cost in favor of the Welsbach will disappear to a great extent in practice; for if ordinary gas burners are replaced by the Welsbach, the total amount of illumination, as a rule, becomes greater, and if

three times as much, the cost of gas to the consumer per month would be the same with the Welsbach as with the ordinary gas burners.

The figures for the acetylene are obtained in the following way:

Assume a plant which is furnishing an illuminating water gas at $1.25 per 1,000 cubic feet. If this plant were converted into a plant to furnish acetylene gas, there are certain expenses, such as the cost for distribution, including the maintenance of the plant, collection of bills, office expenses, etc., that would remain about the same per day for the acetylene as for the water gas. These constant expenses would practically be all other expenses, except those involved in making the gas and storing it in the holder. To simplify matters, let us consider a plant of any given capacity, say, 500,000 cubic feet of gas per day. Then we have:

Paid by consumers per day, 500,000 cubic feet, at $1.25 per 1,000 cubic feet	$625 00
Cost of gas in holder, at 40 cents per 1,000 cubic feet* . .	200 00
Constant expenses per day, together with profit of gas company	$425 00

* The cost of gas stored in the holder is less than 40 cents per 1,000 cubic feet in many large plants, and the price that the gas companies could afford to pay for the carbide would be proportionally reduced. For example, if the gas were stored in the holder for 30 cents per 1,000 cubic feet, the carbide would have to be furnished to the gas company and converted into gas for $30 per ton, to be as cheap as ordinary gas burned in flat-flame burners.

To furnish the consumers with the same amount of light that they obtained with the flat-flame burners and the ordinary illuminating gas, would require one-tenth the volume of acetylene, hence one-tenth of 500,000, or 50,000 cubic feet of acetylene would have to be stored in the holder for $200, in order that there should be the same profit to the gas company. This 50,000 cubic feet would be produced by 5 tons of calcium carbide; hence, the cost of 1 ton of calcium carbide, together with the cost of converting the carbide into gas, would be $40, to compete with ordinary gas at $1.25 per 1,000 cubic feet, burned in flat-flame burners.

To compete with ordinary gas burned in Welsbach burners, the amount of acetylene stored in the holders would be in the ratio of 70 to 200 to the amount of ordinary gas re-

quired for equal illumination; or, we would have to store 175,000 cubic feet in the holder for \$200. In addition to this, the cost of the mantles replaced per day in the Welsbach lamps should be included, which would be \$140, making a total of \$340. To produce the 175,000 cubic feet would require 17·5 tons of calcium carbide, and it would have to be furnished at the gas works and converted into gas at about \$19.50 per ton.

It may be claimed that to replace ordinary gas in an existing plant by acetylene would be making use of a plant much too cumbersome for the purpose, and that the interest on capital investment and depreciation would count more heavily against the acetylene than in a plant specially constructed for the purpose. On the other hand, in a plant specially constructed for acetylene, the system of mains for transmission of the gas would have to be laid with much more care than for ordinary illuminating gas, and special piping might have to be used, so that the capital investment of a specially constructed acetylene gas plant might be as much or more than for one furnishing ordinary illuminating gas.

If one-tenth as much acetylene were used for a given illumination as with the ordinary gas, then, if transmitted through the same system of pipes, the percentage of leakage, based on the amount of gas used by the consumers, would be increased about tenfold; or, if the percentage of leakage in a system had been 5 per cent. with ordinary gas, it would be about 50 per cent. with acetylene, of the gas used by the consumers, or 33 per cent. of the gas stored in the holder.

The system of piping now in place for ordinary illuminating gas would not, therefore, be suitable for the transmission of acetylene gas. If special pipes were laid for the acetylene gas they would be required to carry a less volume of gas for a given illumination, and could be made smaller, but it is probable that the care required to produce tight joints would make it just as expensive to lay them as to lay the pipes for ordinary illuminating gas.

Let us next consider the price calcium carbide must be

sold at to take the place of kerosene in domestic lighting, where the gas is generated on the premises. Assume that the cost of labor to charge the gas generator, and depreciation of the plant, is equal to the cost of labor to fill and repair the oil lamps; then we have to compare the cost of the carbide with the cost of kerosene oil required to produce an equal illumination. It was found by my own experiments that to produce 16 candle-power in an argand, or in a good flat flame lamp required about 0·022 gallons of oil per hour. At 8 cents per gallon this would cost 0·18 cents. To produce 16 candle-power with acetylene requires 0·4 cubic feet of gas per hour, so that 0·4 cubic feet would have to be produced for 0·18 cent, or 10,000 cubic feet for $45. Hence, the carbide would have to be purchased for $45 per ton to be as cheap for equal illumination as kerosene oil. As one pound of the compressed liquid acetylene produces about 14½ cubic feet of gas, it would have to be sold for 6½ cents per pound to be as cheap for a given candle-power of light as kerosene.

In some of the earlier literature on acetylene it was proposed to convert electric lighting plants into plants for the production of acetylene, and thus obtain economic results. This could not be done economically, for only about one-half as much light could be obtained from the acetylene as by using the electricity direct for incandescent lights. The results obtained at Spray show that 2 cubic feet of acetylene gas could be produced per hour per electrical horse-power. This would furnish $2 \times 40 = 80$ candle-power. If the electricity were used direct with incandescent lamps requiring 4½ watts per candle-power, the light produced would be $746 \div 4{\cdot}5 = 166$ candle-power per electrical horse-power, or about twice as great a light as would be produced by the acetylene, as has already been stated.

To be as cheap an illuminant as electricity, therefore, the carbide must be made at some point, say, a water-power, where the cost of the power and attendance is much less than at the lighting station.

It has been shown that for an equal illumination the electric incandescent light costs twice as much as gas when

the latter is burned in flat-flame burners. The incandescent electric light has, however, held its own against the gas light on account of its superior qualities, which are its brilliancy, cleanliness and adaptability. The electric light is also preferable on account of the fact that it does not vitiate the atmosphere with carbonic acid gas, and that it produces a less heating effect than ordinary illuminating gas. It also eliminates the danger of asphyxiation through an accidental leakage of gas. That the incandescent electric light has held its own at a higher cost to the consumer for a given candle-power, is a proof that other elements enter into the problem of artificial lighting as strongly as the cost of a given amount of light. From this standpoint, it may be argued that acetylene, producing as it does a more brilliant light than any now used for interior lighting, and having the quality of showing the complexion in life-like tints, will have its own field, even should it be the most costly style of illumination.

Again, acetylene is now used in place of the calcium light for lantern projections, etc. Were it not for the explosive character of the compressed acetylene, it would be useful for cases of isolated lighting, such as for beacons and light-buoys.

It has also been shown that the Welsbach lamp produces about three times the illumination for a given cost as ordinary illuminating gas burned in a flat-flame burner, but that it is deficient in showing the complexion in lifelike tints. For most classes of work, this defect is not of great enough importance to outweigh the advantage derived from its great economy.

The whole situation may be summed up by saying that each system of lighting has its own field of usefulness, on account of properties peculiar to itself, which make it more desirable than the others for certain classes of work.

REPORT OF TESTS OF A 28-INCH AND 36-INCH "CASCADE" WATER WHEEL MADE AT THE MECHANICAL ENGINEERING LABORATORY OF THE OHIO STATE UNIVERSITY.

ABSTRACT BY JOHN H. COOPER.

As a matter of general information, supplementing the very elaborate communication on the historical development of the type of water wheels known as the "tangential" or impulse water wheel, which was lately published in this *Journal*,* the following record of tests of the efficiency of a modified form of the tangential water wheel, manufactured by James Leffel & Co., Springfield, O., which were made in the mechanical engineering laboratory of the Ohio State University, under the direction of Prof E. A. Hitchcock, Director, will be found to make an interesting contribution to the history of this class of machines.

A brief description of the "Cascade" wheel is introduced, to give the reader an idea of its distinctive features. It is adapted, like others of its class, for use where small quantities of water under very high heads are available.

This wheel has two separate sets of buckets. These buckets are located alternately on each side of a central, sharp, continuous, dividing ridge, projecting a little in front of the entering edge of the buckets. This dividing ridge has a sharp, cutting edge, which serves to divide the jet of water before it touches or reaches the buckets, and to keep it continuously divided in two equal portions, so that each portion of this single jet is received separately on each side of the dividing ridge. One-half of the jet is therefore received by one series of buckets independently of the other half, which is received by the other series. Each series of buckets on each side of this continuous dividing edge is so arranged that no two come opposite each other, and, as a consequence, the buckets of each series catch the water alternately.

The claim is made for this alternating arrangement of buckets that it secures greater steadiness of motion, since

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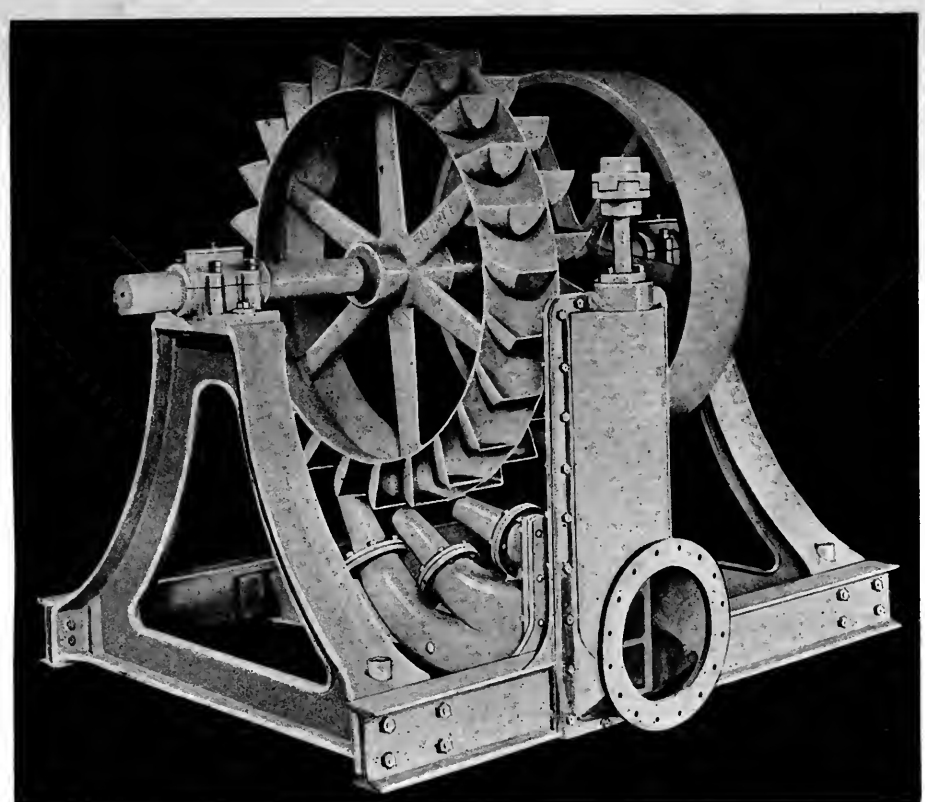

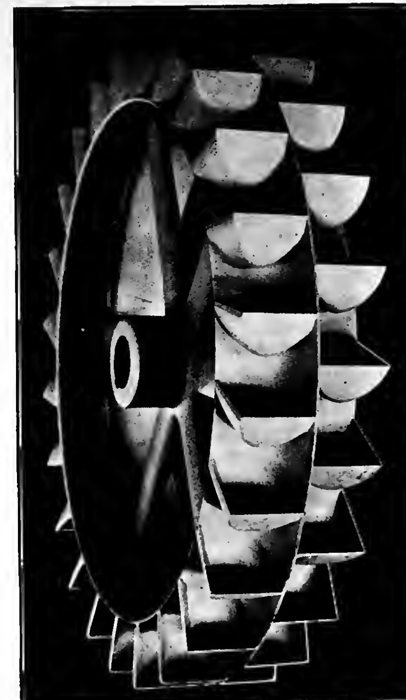

"CASCADE" WATER WHEEL.

it is equivalent to twice the number of buckets, and the impulses are therefore divided more regularly on the wheel, as each bucket passes the point of the nozzle, and catches its half portion of water. These buckets are cast solidly upon each side of the circular dividing ridge and upon the face or rim of the wheel on each side of this central division. This circular ridge being also angular and curved as it approaches the center, gives to the interior of the buckets a symmetrical and effective curve. The further claim is made by the builders that this arrangement of buckets and form of construction secure great strength, firmness and stability, and the buckets are not subject to the difficulty of becoming loose, as those styles in which bolts, nuts and other appliances are used to fasten them upon the face or rim of the runner.

The illustration shown herewith gives a perspective view of the wheel, showing clearly the alternate arrangement of the buckets, and also a view of the wheel mounted in an iron frame and with the side and top of the casing removed, by which the mode of admitting the water through several jets or nozzles is seen. While these nozzles constitute really one piece, the water is admitted separately to each, and the entire system of nozzles is easily set and fastened within the casing upon a light and planed joint. The mode of mounting is such as to permit of moving these jets and thereby varying the inclination at which the water may be projected upon the buckets. Either of the tips or nozzles may be removed, and others, of different size or bore, put in their places, or any of them may be capped over, and one or several or all used as may be desired.

By a modification of the casing or framework, three or more additional jets may be added, extending the stream further around the circumference of the wheel. The usual requirements, however, of this class of wheels will be limited to one, two or three jets, and the number of these and the style of mounting are modified to suit the conditions of each case.

The following table gives the results of a series of tests of this wheel made in the summer of 1896, in the mechanical

engineering laboratory of the Ohio State University, Columbus, O.

It will be observed that there are six tests given on each of two wheels of different sizes running at different speeds. The slight variation in efficiency is attributed to this difference in the number of revolutions.

EFFICIENCY TESTS.

	Head in Pounds.	Head in Feet.	Flow of Water in Pounds per Minute.	Revolutions per Minute.	Brake Load.	Developed Foot-Pounds of Work.	Developed Horse-Power.	Foot-Pounds of Work Expended by Water.	Efficiency.	Velocity of Wheel.
38" Wheel.	75·55	165·3	3,330	309·8	80	495,680	13,662	550,400	90·04	47·75
	71·10	164·2	3,318	331·2	75	496,800	15,054	514,600	91·02	50·83
	71·75	165·7	3,335	273·6	90	492,480	14,924	552,500	89·16	41·66
	63·92	147·7	3,135	337·0	60	404,400	12,254	463,000	87·34	52·08
	67·25	155·3	3,222	336·0	65	436,800	13,236	500,350	87·30	52·02
	67·95	157·0	3,238	316·2	70	442,680	13,414	508,350	87·06	48·75
26" Wheel.	70·15	160·0	2,075	482·8	30	283,680	8,778	331,980	87·23	49·80
	70·75	153·4	2,085	447·0	35	312,900	9,482	340,689	91·85	46·20
	70·35	162·5	2,078	377·4	40	301,920	9,149	337,675	89·40	37·95
	71·35	164·8	3,324	491·8	50	491,800	14,903	560,400	87·76	50·90
	71·95	166·2	3,340	445·2	55	489,720	14,840	555,108	88·20	46·25
	70·65	163·2	3,309	400·0	60	480,000	14,545	540,000	88·88	41·50

Great care was taken in making the preparations for these tests and in conducting them, and the authors believe that the results announced may be accepted as thoroughly accurate and reliable. The average efficiency in each case, it will be observed, is very high.

These tests were made by Messrs. L. A. Frayer, Maurice Donham and Raymond Cilley, of the senior class of the University, under the supervision and inspection of Prof. E. A. Hitchcock, head of the mechanical engineering department. J. H. C.

CHEMICAL SECTION.

Stated Meeting, Tuesday, March 16, 1897.

DR. JOS. W. RICHARDS, President, in the chair.

RELATIONS BETWEEN THE MELTING POINTS AND THE LATENT HEATS OF FUSION OF THE METALS.

By JOSEPH W. RICHARDS, PH.D.

In a lecture before this Institute in January, 1893, on "The Specific Heats of the Metals," I announced the fact that in the case of most of the metals whose latent heats of fusion were known, this quantity bears a simple relation to the heat required to raise the metal from absolute zero (— 273° C.) to its melting point. In most cases the former is one-third the latter. I even ventured to predict that the latent heat of fusion of gold was about 14 calories, and it has since been determined by Roberts-Austen as 16·3. Further, several latent heats have since been determined which conform to the above relation, and I have thought it opportune to collect these data and point out the limits of the relation, with some other observations which later thought on the subject has developed.

In the following table there is given, first, the heat required to raise 1 kilogram of the metal from the absolute zero to its melting point (using the most probable values for the specific heats and exterpolating to — 273°, for a discussion of which data reference is made to the paper already quoted); second, a simple fraction of this quantity and, lastly, the actually determined latent heats of fusion, the experimental errors of which are probably 5 to 10 per cent.:

Element.	Heat Absorbed from — 273° C. to the Melting Point.		Latent Heat of Fusion (Experimental).
Sodium	107·8	⅓ = 35·9	32·7
Aluminium	215·0	½ = 107·5	100·0
Potassium	54·9	⅓ = 18·3	15·7
Copper	145·3	⅓ = 48·4	43·0
Zinc	71·2	⅓ = 23·4	22·6
Gallium	21·9	$\frac{1}{1}$ = 21·9	19·2
Palladium	125·0	⅓ = 41·7	36·3
Silver	74·7	⅓ = 24·9	24·7
Cadmium	30·7	⅓ = 10·2	13·1
Tin	27·6	½ = 13·8	14·5
Platinum	83·4	⅓ = 27·8	27·2
Gold	45·3	⅓ = 15·1	16·3
Mercury	7·5	⅓ = 2·5	2·8
Lead	17·7	⅓ = 5·9	5·4
Bismuth	14·4	$\frac{1}{1}$ = 14·4	12·4

Of the fifteen cases, the relation in eleven cases is one-third (in almost every case within the limits of the experimental errors); in two cases the fraction is apparently one-half, and in two cases unity. That for ten cases the ratio should be so uniform, with latent heats ranging from less than 3 to nearly 50, is an indication of some intimate connection between these physical constants of the elements.

Regarding the exceptional cases, it occurred to me that aluminium, tin and bismuth are known to act anomalously in many relations, as if their molecular structures were different from that of the other metals. (We have no data from which to discuss Gallium in these relations.) For instance, in lowering the freezing point of other metals, aluminium is known to act as if its molecular formula were double that of other metals in the molten state. In Pictet's observation of the connection between the melting point, coefficient of expansion and atomic volume of an element, bismuth and tin are among the chief exceptions.

[Pictet's rule is that the melting points of the elements (T, in absolute degrees) are, in many cases, inversely proportional to their coefficient of expansion by heat (a = linear expansion 0° to 100° C.) and to the relative distance of their atoms apart ($\sqrt[3]{V}$, where V is the atomic weight

divided by the specific gravity, or atomic volume) for which Pictet's relation is expressed by

$$T \cdot a \cdot \sqrt[3]{V} = 4{\cdot}5$$

or

$$T = \frac{4{\cdot}5}{a \cdot \sqrt[3]{V}}.$$

In fact, the products of these three quantities are not exactly equal, but vary between 4 and 5, the reason being, doubtless, that the average specific gravity and rate of expansion from — 273° to the melting point varies somewhat from the gravity at 20° and rate of expansion at 0° to 100° as used in his calculations.]

As already mentioned, bismuth and tin were Pictet's chief exceptions, and since they were anomalous in regard to their latent heat relations, I was led to compare these several relations among themselves, and to the following chain of reasoning: Since the atomic heats of the elements (specific heat into atomic weight) at 20° to 100° are, by Dulong and Petit's law, approximately equal to 6·4, then, assuming that the average specific heat from — 273° to the melting point does not vary much from the figure for 20° to 100°, the heat in atomic weight of a metal at its melting point is approximately 6·4 T; and, assuming the relation between the latent heat of fusion and the total heat in the metal at its melting point as $\frac{1}{3}$, the latent heat of fusion of an atomic weight of a metal becomes approximately 2·1 T.

But we can at once connect this expression with Pictet's rule, and write:

$$L = 2{\cdot}1\ T = \frac{4{\cdot}5 \times 2{\cdot}1}{a \cdot \sqrt[3]{V}} = \frac{9{\cdot}5}{a \cdot \sqrt[3]{V}},$$

where L is the latent heat of fusion of an atomic weight of the metal.

To test the validity of this expression (which, for reasons already explained, cannot claim exact accuracy), we will take Pictet's values for $a \cdot \sqrt[3]{V}$ (which are based on the best available data) and make the calculation for the metals whose latent heat of fusion and coefficient of expansion are both known.

	$L = \frac{9 \cdot 5}{a \cdot \sqrt[3]{V}}$	$\frac{L}{At. Wt.}$ = for 1 kilo.	Latent heat experimentally obtained.
Aluminium	1,900	70·4	100·0
Copper	3,006	46·2	43·0
Zinc	1,561	24·6	22·6
Palladium	3,832	36·1	36·3
Silver	2,541	23·5	24·7
Cadmium	1,253	11·1	13·1
Tin	1,712	13·7	14·5
Platinum	5,106	26·3	27·2
Gold	3,035	15·5	16·3
Mercury	654	3·3	2·8
Lead	1,284	6·2	5·4
Bismuth	2,777	13·4	12·4

Excepting aluminium, the coincidences are so close in the case of all the others that the calculated values in every case fall within the permissible limits of experimental errors, and it must be remembered that the above table contains *all* the metals for which the data are at present available. The non-metal sulphur expands so irregularly that no calculation can be made for it.

The closeness of the above coincidences may lead us to apply the formula to those other elements whose coefficients of expansion are known, but whose latent heat has not yet been determined, and thus to predict approximately the probable value of their latent heat of fusion.

	Calories.
Magnesium	58·
Pure iron	69·
Cobalt	68·
Nickel	68·
Selenium	13·
Ruthenium	46·
Rhodium	52·
Indium	8·
Antimony	16·
Tellurium	17·
Osmium	35·
Iridium	28·
Thallium	5·8

In the case of those other elements whose coefficients of expansion and specific heat are both unknown, the latent heats of fusion may be predicted, approximately, simply from the melting point, by using the relation $L = 2{\cdot}1\ T$.

The above comparisons, however, have shown that the dependence of the atomic latent heat of fusion on the absolute temperature of the melting point, or on the total heat in the metal at its melting point, is less exact than the dependence on the coefficient of expansion and atomic volume; and we should give the latter relationship preference in predicting unknown latent heats.

NOTES AND COMMENTS.*

CALCIUM CARBIDE AS A REDUCING AGENT.

BY H. N. WARREN.

The author says, in the *Chemical News*, that since the introduction of this remarkable substance, it is significant that scientific men have been content to allow the product to rank solely as a water decomposer, and thus regard the production of acetylene the only available product. Researches of a somewhat lengthy description, which have lately been carried out at the Liverpool Research Laboratory, involve the use of calcium carbide as a metallurgical reducing agent.

In the first instance an excess of litharge was heated to redness in contact with the carbide, in a clay crucible, the reaction being accompanied by vivid incandescence, resulting in the formation of metallic lead and calcium oxide, CaO. A further portion was now selected, in which the proportion of carbide exceeded that of the litharge; this was further subdivided into various smaller portions, each portion being exposed to various temperatures, resulting in a regulus of calcium and lead of varying percentage, together with the expulsion of CO_2.

The alloys thus formed are all more or less brittle, and to a certain extent sonorous when struck, their melting-point ranking below that of pure lead, and are slowly, but completely, decomposed in contact with aqueous vapor, the reaction being much less energetic than that afforded by alloys of lead with the alkaline metals. Stannic oxide, cupric oxide, and also ferric oxide, at corresponding higher temperatures, were readily reduced, yielding results of no practical value; in the case of the cupric alloys those samples containing under 1 per cent. of calcium being rendered cold-short and breaking under very small strain; while, on the other hand, iron containing calcium approaches in appearance that of ferro-manganese, being even more brittle, and very oxidizable in contact with water.

In a further operation, oxides of manganese, nickel, cobalt and even chromium, molybdenum and tungsten were readily reduced, yielding calcium alloys. Results of experiments comprising the reductive action of the carbide upon the earthy chlorides and their haloids will be shortly at hand. The already partial success of these reactions seems to point most conclusively

* From the Secretary's monthly reports.

toward a new and powerful reducing agent, which at the same time, considering the market value of the carbide in question, could not fail to replace both sodium and potassium.

PHOTOGRAPHY IN NATURAL COLORS.

According to a recent article in the London *Times*, a decided advance has been made in color photography, and one which appears to give results of great practical value. M. Villedieu Chassagne, of Paris, has lately submitted to the Society of Arts a process, the joint invention of himself and Dr. Adrien Michel Dansac, by which photographs can be produced showing the actual colors of the objects photographed. The process is a simple and inexpensive one. A negative is taken on a gelatine plate, which has been treated with a solution of certain salts; the nature of the solutions used is for the present kept secret. The negative is developed and fixed in the ordinary way, and, when finished, looks like any other negative. From it a positive is printed on sensitized paper or on a gelatine film (if a transparency is desired), plate or paper having previously been treated with the unknown solution. The positive looks exactly like an ordinary photographic print or transparency, and shows no trace of color. It is then washed over with three colored solutions, blue, green and red, and it takes up in succession the appropriate color in the appropriate parts, the combinations of the colors giving all varieties of tint. Thus, in a landscape, the trees take on various hues of green, the sky becomes blue, the flowers show their proper colors, the bricks and tiles of the houses are red, and so on. In a portrait the flesh tints come out well, and the different colors of the costume are accurately given. The general appearance of the picture is that of a colored photograph. Looked at from a distance, it would be taken for one. Inspected under a high magnifying power, it is seen that the colors follow the details in a manner hardly possible for hand-work. Further and independent investigation will no doubt throw some light on the principles involved. At present no explanation can be offered. The inventor himself does not profess to offer any, and, until further information is available, all speculation must be mere guesswork. It is to be said, however, that the subject certainly looks as if it would repay scientific examination and increase scientific knowledge.

SCIENTIFIC BREVITIES.

Gunz and Masson, continuing the experiments of the former, have shown that *aluminum will reduce CO or CO_2*. They find that, at a high temperature, in the presence of a little iodide or chloride of aluminum, aluminum is readily burned in a current of CO or CO_2. With CO the reaction is expressed by the following equation: $6Al + 3CO = Al_2O_3 + C_3Al_4$. On treating with boiling water, the aluminum carbide gives practically pure methane.——Trowbridge and Richards have proved that *argon*, at low pressures, *gives a blue fluorescence* under the action of the Herzian waves. The *Scientific American* reports the fact that *a self-toning collodion sensitized*

paper is prepared by coating the paper with a collodion emulsion mixed with the silver and the toning chemicals, such as chloride of gold. When a sheet of the paper is placed in the printing frame behind a negative the printing takes place in the usual way, but instead of being a red color it prints the same color as the ordinarily finished print does, the operation being continued until the print looks a trifle darker than is desired. It is then placed directly in a fixing bath composed of hyposulphite of soda and water for a few minutes, washed in changing water for half an hour, then dried and mounted. The prints are very satisfactory, equalling in brilliancy those made in the ordinary way, and are said to be fully as permanent.——Apropos to the rapidity with which Röntgen photographs can now be taken, London *Nature* refers to a series of pictures recently shown by Dr. John Macintyre at the Glasgow Philosophical Society. Dr. Macintyre passed through a kinematograph a film 35 feet long, having upon it radiographs of a limb of a frog, and he was thus able to show distinctly to a large audience the movements of the bones in the limb. To obtain the photographs the kinematograph was covered with lead in which there was the usual aperture. This aperture was covered with black paper. The tube was then put in the best condition, the mercury interrupter being used with a 10-inch spark coil. The movements of the limb of the frog were controlled by a mechanical arrangement.——As germane to the foregoing item, the fact appears to be well established that *prolonged exposure to the* direct action of the *Röntgen rays* is followed, at least in the case of some persons, by an injurious action upon the skin. A case was recently reported in the electrical journals (that of a boy of 10 years old) in which exposure of the cranium to the X-rays was followed, after the lapse of a few days, by the sudden falling out of the hair over the portion of the skull exposed. Reports of serious skin affections from the same cause have been reported. The latest account of this kind is given in the *Bulletin* of the Johns Hopkins Hospital. The writer, Mr. T. C. Gilchrist, after reviewing the several cases, finds that the X-rays are even more powerful than have been generally thought, and that the deleterious effects may, in some cases, be quite serious; the cutaneous manifestations are not, however, the most severe of the lesions, but they are surpassed in severity by those of the deeper tissues, and particularly of periosteum and bones. The discovery of this deeper and more profound effect calls for a new explanation to account for the cutaneous lesions. It seems probable that, according to the writer, these injurious effects may be due to the platinum particles piercing the bulb and then attacking the tissues. On clinical grounds, he states, there is considerable support for this, at first sight, improbable theory. If the lesion extends at all deeply it leads to the formation of ulcers, which are extremely intractable, and they may be due to irritating particles still present in the tissues. Mr. Gilchrist advises X-ray operators and experimenters, who develop any special idiosyncrasy, to abstain from their use if they find that the slightest deleterious results follow an exposure to them.——M. Henri Léon, in an essay on the *saltness of sea water*, gives in the Monthly Bulletin of the Biarritz Association the results of

analyses of water from different seas, which is thus summarized in the *Scientific American:* Taking 1,000 grammes of water, the result showed in the Atlantic 32·657 grammes of saline matter, in the Mediterranean 43·735, in the Black Sea 17·663, in the Sea of Azov 118·795, and in the Caspian 62·942. Among the saline matter chloride of sodium varied considerably. The sea was found to be less salt near the poles than at the equator, and was more salt at a distance from land and where it was of great depth than near the land and shallow. The Mediterranean is the exception, which is explained by the comparatively few rivers that freshen its waters. Salt lakes are frequently more salt than the ocean, as, for instance, the Dead Sea, which is ten times salter than the Atlantic.——From the same source we learn that some interesting investigations have been made on the *green color for which some Italian cheeses are so remarkable.* This color is not, as has sometimes been supposed, due to the action of bacteria, but is a consequence of the presence of copper in the cheese. To produce a good Parmesan cheese, the milk must reach a high degree of acidity, and, while waiting for this proper pitch of acidity to be acquired, the milk in some parts of Italy is kept standing in copper vessels. During this period of repose the milk takes up considerable quantities of copper; indeed, it is customary to estimate the degree of acidity attained by the milk by noting the gradual disappearance of the brightness of the highly polished, metallic surface. Dr. Mariani has examined twenty-five samples of green Parmesan cheese from various places, and has found that to about every 2 pounds of cheese there is present from 0·8 to 3·3 grains of copper. That this metal is solely responsible for the green color is evident from the fact that in the south of Italy cheese manufactured on the same principle, but in which the milk stands in tin-lined instead of copper vessels, does not acquire any green color.——Some recent observations made at the Howard College Observatory, on the spectrum of the star charted as *Zeta Puppis,* in addition to certain other peculiarities, have disclosed the existence on that body of *a new element* not found on the earth or on any other stars. The new substance resembles hydrogen, although it is quite distinct from it.——In the London *Electrician,* Leeds criticizes certain recent publications to the effect that a great revolution in *the art of producing aluminum* may be looked for within the next decade. His conclusions are adverse to this view. At present there is really only one method in use; it is highly probable that bauxite will remain the only available ore, as clay contains too little of the metal and too much silica, and cryolite is difficult to procure or reduce and is too impure. Several of the suggestions made are said to be visionary, and it is thought that the only alterations in the present method which are likely to take place will be in details effecting a decrease in price. If the present price could be reduced to one-half, aluminum would immediately become available as a conductor in the place of copper. W.

TECHNICAL BREVITIES.

The annual estimate made by Prof. W. C. Day, of the United States Geological Survey, regarding the *slate production of the United States for*

1896, shows the output of roofing slate last year to have amounted to 673,304 squares, valued at $2,263,748, while the production of slate for other purposes was valued at $482,457. Of this amount, Pennsylvania produced slate for roofing purposes of the value of $1,391,539, and for other purposes of the value of $334,770. The value of the total slate output of the United States showed an increase of $47,505, as compared with 1895. The increase, however, was entirely accounted for by the remarkably large export trade in roofing slates which developed in the latter half of 1896, owing to the strikes in the Welsh quarries. The home consumption fell considerably behind that of the previous year.——The Carborundum Company reports to the *Engineering and Mining Journal*, that its works have produced, during the year 1896, in round numbers, 1,191,000 pounds, or 595¼ tons, of crystalline carborundum. Consideration at the present is given to the production in crystalline form only, but another important industry, in which carbide of silicon promises to be a valuable adjunct, will naturally increase the usefulness of the material. Some mention has been made of the experiments showing that carborundum can be used, and will, in all probability, take the place of ferrosilicon in the manufacture of steel. Prof. Luehrmann, of Germany, recently wrote an article on this subject, indicating that in the use of carborundum there might be, in Germany alone, approximately, 2,500 tons consumed annually, provided its cost would not exceed 6 cents per pound. The amorphous form may be used for this purpose, and the Carborundum Company is prepared to furnish it at a price slightly under this figure.——By the consolidation of the two great iron manufacturing firms of Schneider and Canet, of Paris, the heads of the two foundries visited President Faure recently, and assured him that France now has *an iron manufacturing plant rivalling the Krupp establishment in Germany*.——The New *Panama Canal Company*, which is now said to be quietly but steadily working upon the construction of a lock-canal, was organized in Paris on October 1, 1894, just in time to save the concession from Colombia, which expired on October 31, 1894. Stockholders subscribed $4,000,000 toward the work, and from some of the promoters of the old company a further sum of $3,400,000 was forced. The report of the commission of Dutch, Belgian and French engineers, submitted in May, 1890, estimates that a lock-canal could be built for $180,000,000, including interest on the investment and 20 per cent. for contingencies. The United States of Colombia has granted a further concession, extending the time of completion to 1904. Under the present administration, it is claimed that the strictest economy is being practiced, and the latest devices for cheaply handling earth and rock are being introduced.——Dispatches from London, dated April 3d, say that the reports of the recent trial trips of the *roller steamer* at Rouen have been discouraging, the engines not proving powerful enough. Their power was nearly trebled, but the increased weight submerges the rollers so deep that they only turn ten times a minute instead of forty. The rollers throw up such quantities of water behind that each acts like a brake and reduces the anticipated 30 knots an hour to 6 or 7. Rubber scrapers are being experimented with to prevent the upheaval of the water.——*The Scientific American* states that a company engaged in the manufacture of *electric*

hansom cabs is now endeavoring, in New York, to compete with ordinary cabs drawn by horses. It was quite a time before the company could obtain the necessary permission to run its cabs for hire upon the streets, but the licenses having been obtained, the cabs are now a well-known sight in the upper part of New York, and occasionally they may be seen going as far down-town as Wall Street, winding in among the trucks and cable cars. This open competiton with horse-drawn vehicles may be regarded as one of the most satisfactory events in the motor-carriage world for a long time. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, April 21, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 78 members and visitors.

Mr. Washington Jones was elected to the Board of Managers for the unexpired term of Mr. Theo. D. Rand, elected Vice-President.

Mr. Otto C. Wolf was elected to the Committee on Science and the Arts for the unexpired term of Prof. Arthur Beardsley, resigned.

The regular order of business was suspended, at the President's suggestion, and the meeting was devoted to the subject announced for discussion, viz.: "The Smoke Nuisance and its Regulation."

The discussion was introduced by a paper from Mr. A. E. Outerbridge, Jr., giving a brief historical sketch of the subject, and some data having especial reference to the smoke question as it affects Philadelphia.

The discussion was continued by brief addresses from the following members and others: Prof. R. H. Thurston, Ithaca, N. Y.; Mr. Wm. R. Roney, Baltimore, Md.; Mr. Wm. F. Durfee, West New Brighton, N. Y.; Mr. Edward Longstreth, Prof. Lewis M. Haupt, D. Ashworth & Son, Pittsburgh, Pa.; Col. Thos. P. Roberts, Engineer Monongahela Navigation Company, Pittsburgh, Pa.; Mr. Max Livingstone, Mr. Wm. M. Barr, Mr. James Christie, Mr. Arthur Kitson and Dr. Wm. H. Ford, President of the Philadelphia Board of Health.

The discussion was carried on until a late hour, and, on motion, its continuation was postponed until the stated meeting of May 19th.

[The discussion will be published in full in the *Journal*.]

Adjourned. WM. H. WAHL, *Secretary*.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held April 7, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading:

Knife-Sharpener Attachment for Sewing Machines, Mary H. P. Cox.

Battery-Motor, A. A. Kent.

The Venturi Meter, Clemens Herschell, C. E., Providence, R. I. (Report of progress.)

Reports on the following subjects were adopted:

Black-Prints.—Process of Francis Leclere, Philadelphia.

ABSTRACT.—The products submitted by applicant are the results of a photo-chemical printing process. The term "black-prints" serves to distinguish these from the analogous products known as "blue-prints." The method is a copying process whereby a positive copy is obtained directly from a positive original, which latter must be transparent or translucent.

The method is briefly as follows: The paper sized, treated with the photogenic compound and dried, is exposed to the action of light under the design to be copied. The time required for exposure is short, as the paper is very sensitive. The exposed paper is then submitted successively to two liquids; the first, which acts as a mordant, and the second as a dye, which varies according to the color desired. The paper is floated on this liquid and absorbs the coloring pigment in the lines and spaces, which had previously been shielded from the action of light. The superfluous dye is washed out and the design appears on the white background of the paper in the desired color.

The report commends highly the quality of the results obtained, and gives the inventor credit for having demonstrated the utility of the process from the standpoint of economic production. The Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Louis E. Levy, Samuel Sartain, Arthur Beardsley, John Haug.]

Piston Packing.—Edward F. Peacock, Philadelphia.

ABSTRACT.—The novel feature of this invention consists in the adaptation of a break-joint block of a piston-packing ring of the Ramsbottom type, for the purpose of preventing the escape of steam through the cut in the well-known Ramsbottom ring. The invention is held to be of doubtful utility. Covered by U. S. letters-patent, No. 407,370, July 23, 1889. [*Sub-Committee.*—J. M. Emanuel, H. F. Colvin, J. Logan Fitts, T. Carpenter Smith.]

Sand Track.—Claus Koepcke, Dresden, Saxony.

ABSTRACT.—The object of this inventon is to arrest the speed of a "wild train" quickly and safely without derailment or ditching, by means of an auxiliary track of standard gauge laid alongside the main track, and connected therewith by the usual switches and signals. This auxiliary track is laid at a slightly lower level than the main track, and is submerged in sand or other resistant material, confined by lateral stringers so as to constitute a trough into which the "wild train" is directed by the switch. The invention has been practically applied and tested in the railway yard in Dresden, and the results reported are highly satisfactory. The report recommends the invention to the attention of railway managers. Protected by U. S. letters-patent,

No. 494,718, April 4, 1893. [*Sub-Committee.*—Messrs. Lewis M. Haupt, Edgar Marburg, James Christie, H. F. Colvin, John L. Gill, Jr., S. M. Vauclain.]

Self-Cleansing Water Filter.—John W. Jarrett, Philadelphia.

ABSTRACT.—This device is intended for filtering water for manufacturing and domestic purposes. The filtering chamber, usually of cylindrical form, is provided at both ends with convex partitions of perforated sheet metal, called distributors, intended to check the force of the water entering the chamber. These distributors are held in place between flanges, by which the cylindrical shell and the heads are united; and between these flanges also, is placed, above and below, a sieve or strainer of wire gauze or other suitable substance. This arrangement of parts is held firmly united by means of exterior tie-rods. A lateral connection at the heads, above and below, is made to accommodate a pipe which has lateral inlet and outlet branches, by means of which, and a two-way cock, the direction of the entering and outflowing water-current may be directed either to the top or the bottom of the filtering chamber. By setting the lever controlling the two-way cock in one position, the course of the water is directed into the top of the filtering chamber, through the filtering material, of whatsoever character, out through the branch pipe at the bottom, at the upper part of which it is deflected by the discharge put through the lateral branch-pipe intended to deliver filtered water.

To cleanse the filter, it is simply necessary to reverse the position of the cock, when the course of the entering water is deflected into the bottom head, and passing through the filter head from below upwards, thoroughly agitates the same, carries the entangled foreign matter contained therein upwards, and discharges the impurities with the effluent water through the branch pipe at the top of the filter chamber. When the washing operation is completed, the position of the valve is again reversed, and the filtering operation is re-established.

The report admits the utility of the apparatus for its intended purpose, but does not recognize therein any element of novelty or originality of sufficient importance to warrant special commendation. Protected by U. S. letters-patent, No. 541,755, June 25, 1895. [*Sub-Committee.*—Samuel P. Sadtler, Frank P. Brown, Reuben Haines].

Flexible Metallic Tube.—T. R. Almond, Brooklyn, N. Y.

This tube consists of two helical coils, one inside the other, so disposed in relation to each other that the outside coil closes the space between the convolutions of the inside coil. The inside coil is originally wound perfectly close, and as the outside coil is wound over it, its convolutions are forced apart, the resulting tension effecting a close joint between the two coils. In the samples submitted for examination, the inside coil is of circular section, and the outer one of triangular section, the base of the triangle being on the outside and the apex on the inside of the coil.

Tubes which are not required to be air-tight (those, for instance, intended to support incandescent electric lamps) have the outside coil made of wire, the section of which is an equilateral triangle, while a more obtuse vertical angle is used for tubes intended to conduct fluids or gases, so as to obtain a greater normal pressure on the joint. These tubes are designed for use as adjustable supports for incandescent electric lights, for conducting oil or other

lubricating fluids to drills, boring tools, etc.; for conducting air to blow-pipes, etc. The tubes designed for conducting fluids were found to be perfectly tight against leakage and well adapted for their intended purpose. The "very conservative" claims of the inventor were found to be more than sustained. Protected by U. S. letters-patent, No. 424,044, March 25, 1890.

The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—Messrs. Hugo Bilgram, Robert D. Kinney, T. Carpenter Smith, Luther L. Cheney, J. Logan Fitts.

FOLLOWING is a list of applications received, and subjects referred by the Institute, for investigation by the Committee, since January 1, 1897:

No. 1950. Almond's Flexible Tubes, Application filed January 13.
" 1951. Koepcke's Sand-Track, Application filed January 21.
" 1952. Robertson's Nutritious Bread, Application filed January 29.
" 1953. Moissan's Investigations with the Electric Furnace, Investigation ordered March 6.
" 1954. Praul's Aërial Motor, Application filed February 26.
" 1955. Richards' Automatic Fluid-Pressure Friction Clutch, Application filed March 8.
" 1956. Williams' Typewriting Machine, Application filed March 8.
" 1957. Marsh's Metallic Corner Bead, Application filed March 9.
" 1958. Mueller's Process of and Apparatus for Manufacturing Mosaics, etc., Application filed March 10.
" 1959. Cox's Knife-Sharpener, Application filed March 12.
" 1960. Lewis' Improvement in Rotary Steam Engines, Application filed March 13.
" 1961. Corscaden's All-Wrought-Steel Belt Pulley, Application filed March 13.
" 1962. Groves' Gear Moulding Machine, Application filed March 15.
" 1963. Abatement of the Smoke Nuisance, Referred by Institute March 17.
" 1964. Dunn's Method for Measuring Intensities of Impulsive Forces, Referred by Institute March 17.
" 1965. Markley's Improvement in Wheels, Application filed March 20.
" 1966. Davis' Balanced Locomotive Driving-Wheel, Application filed March 23.
" 1967. Sanguinetti's Window Ventilator, Application filed April 7.
" 1968. Hollingshead's Automatic Disinfectant Ejector, Application filed April 8.
" 1969. Cazin's Percussion Wheel, Application filed April 19.
" 1970. Morrell's Duplication of the Cube, Application filed April 22.

W.

SECTIONS.

CHEMICAL SECTION.—The stated meeting Tuesday, April 20th, was devoted to a lecture by Dr. Henry Leffmann; subject, "The Chemistry of Food Adulteration." (To be published.)

ELECTRICAL SECTION.—The following card of proceedings is issued for the stated meeting of Tuesday, April 27th:

H. Lyman Sayen will exhibit and describe his "New Form of Crookes Tube, with Automatically Adjustable Vacuum; also Some New Forms of X-Ray Apparatus."

F. H. Lincoln, "Emergency Engineering," following the recent fire at the power station (Thirteenth and Mt. Vernon Streets) of the Union Traction Company.

C. J. Toerring, "The Enclosed Arc."

MINING AND METALLURGICAL SECTION.—The Board of Managers, at its stated meeting of Wednesday, April 14th, approved the formation of a Mining and Metallurgical Section, on the petition of the undermentioned members:

A. W. Allen,
Clarence S. Bement,
John Birkinbine,
E. S. Balch,
Andrew A. Blair,
Wm. Henry Bower,
Wm. A. Bullock,
James Christie,
Thomas P. Conard,
Walton Clark,
James deBenneville,
W. F. Durfee,
Chas. B. Dudley,
E. V. d'Invilliers,
Theo. N. Ely,
Jacob B. Eckfeldt,
Francis Wyatt,
Amos P. Brown,
Jos. Hartshorne,
T. M. Drown,
W. S. Noyes,
Lee K. Frankel,
Henry Gawthrop,
Fred. A. Genth, Jr.,
Fred. A. Gordon,
F. L. Garrison,
Lyman B. Hall,
Wm. C. Henderson,
Morris P. Janney,
Walter M. James,
Harry F. Keller,
Benj. S. Lyman,
Henry G. Morris,
H. S. Miner,
Tinius Olsen,
A. E. Outerbridge, Jr.,
Theo. D. Rand,
Wm. Tatham,
Wm. C. Day,
John M. Hartman,
Wm. H. Greene,
C. J. Reed,
Jos. Richards,
Jos. W. Richards,
Fred. A. Riehlé,
Wm. Sellers,
F. Schumann,
Frank Shuman,
Waldron Shapleigh,
H. T. Townsend,
D. K. Tuttle,
Jos. Willcox,
Wm. H. Wahl,
W. R. Webster,
Jos. Westesson,
Asa W. Whitney,
Walter Wood,
James M. Dodge,
Chas. James,
J. Pitman,
Thos. S. Parvin,
Wm. Burnham.

The first meeting for organization was held on Wednesday, April 28th, at 8 P.M. The following is the program:

Opening Address, Mr. John Birkinbine, President of the Institute.

"The Undeveloped Mineral Wealth of Newfoundland." Mr. A. E. Outerbridge, Jr.

"Compass Variation as Affected by Geological Structure in Bucks and Montgomery Counties, Pennsylvania." Mr. B. S. Lyman.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLIII | JUNE, 1897 | NO. 6

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE FRANKLIN INSTITUTE.

Stated Meeting, April 21, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH SPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA.

DISCUSSION.

THE PRESIDENT opened the subject by reference to the circumstance that the Board of Health of the city of Philadelphia had requested the appointment, by the Franklin Institute, of a committee to co-operate with the Board, in considering ways and means for the abatement of the growing evils arising from the increasing use of bituminous coal within the city limits. He announced that Mr. A. E. Outerbridge, Jr., had been invited to open the discussion.

A. E. OUTERBRIDGE, JR.:—In accepting the invitation

of the Secretary of the Institute to open this discussion, I assume that a *résumé* of the scientific investigations that have been made in the past, and a brief statement of the general principles underlying the problem of prevention or abatement of the smoke nuisance, will suffice to indicate the scope of the inquiry which we have been requested by the Board of Health of Philadelphia to make, with a view of offering some practical suggestions to aid that body in preparing a suitable smoke ordinance, should we find it feasible and advisable, for presentation to the Mayor and Councils.

The subject is by no means a novel one, although it is true that factories in America were formerly established, as a rule, in sparsely settled districts, where fuel was cheap and smoke prevention was not an important consideration. The present high price of anthracite coal, compared with the greatly decreased cost of bituminous coal, is now causing manufacturers in this city to reluctantly discard the more costly fuel and to substitute the cheaper, smoke-producing bituminuous coal.

Formerly the smoke-stacks of factories in this city towered high above neighboring buildings, and the smoke, when emitted, was carried away by the winds, causing little annoyance to the neighbors. The development of modern "sky-scraper" office buildings surrounding industrial establishments, far overtopping their chimneys, is rapidly changing these old conditions, and the question of prevention or abatement of discharge of black smoke from the chimneys of such factories within the city limits has now become an important problem, which cannot be longer put aside.

It is not the first time that the services of this Institute have been requested by the city authorities in discussing and solving municipal engineering and mechanical questions. The results of such deliberations have heretofore proved beneficial to the city and creditable to the reputation of the Institute. The present topic is a fitting one for our consideration, and it requires very careful and judicious treatment. The purpose of the foundation of this Institution was, and its motto is: "The promotion of the mechanic arts." It is, therefore, self-evident that no legislation

which would tend to injure or embarrass any of our great industries would be likely to meet with favor. On the other hand, and for this reason, any practical suggestions which we may be enabled to make, looking to smoke abatement, will carry great weight with the City Councils, with manufacturers, and with all people interested in the comfort and health of our citizens, the cleanliness and beauty of our public buildings, private dwellings and streets, and, in a word, in the continued prosperity of this great manufacturing city in the future.

In the course of some investigations made during the past year, I have found that unwise and ignorant legislation has been the chief cause of failure of some of the smoke ordinances which have been passed in several Western cities where soft coal is the principal fuel used.

Here, for example, is an ordinance more than ten years old, making it a penitentiary offence for an individual to permit black smoke to escape from his chimney. I doubt if any such offender (in the city which shall be nameless) has ever been so punished. The very absurd and preposterous nature of the penalty made the ordinance practically a "dead letter" from its inception. Other ordinances in the collection now before you vary greatly with respect to their inherent merits; some are comparatively good, some are positively bad, but all are, no doubt, capable of improvement.

The president of the Board of Health of Philadelphia has been the recipient of numerous complaints from citizens—more especially since the recent large increase in the use of bituminous coal in industrial establishments—of annoyance from smoke discharge, and, wishing to avoid mistakes, has placed the matter in our hands for investigation and advice, and our Board of Managers has wisely concluded, in order to insure a full discussion of the subject, to authorize the secretary to issue a call for a sort of scientific "town meeting," to which a general invitation has been extended.

I am informed that quite a number of gentlemen from this city and elsewhere, who are practically familiar with the subject to be discussed, have accepted the invitation

and are present and prepared to offer their views to-night. I will, therefore, merely give you, in an informal, conversational way, an outline of the subject to be discussed, indicating also the proper road which I think we should travel, and to which we should confine ourselves.

More than fifty years ago the way was prepared in England by the appointment of a royal commission of fifteen distinguished scientists, manufacturers and others, including the Lord Mayor of London, to investigate the subject of the smoke nuisance in that city. A vast amount of testimony was taken, and valuable information gathered from a variety of sources.

Three fundamental questions were formulated and propounded to many persons skilled in the arts and sciences, viz:

(1) Is it practicable to prevent or diminish the discharge of smoke?

(2) Is it advisable?

(3) In the event of an affirmative, answer would you recommend legislative enactment?

The concensus of opinion was that the discharge of black smoke was merely the visible sign of imperfect combustion, and that the time would certainly come when it would be both practicable and necessary to prevent such discharge.

That this time has now come—certainly in so far as it applies to smoke discharge from chimneys of stationary boilers—you will, I think, be convinced by the arguments of various speakers present, who have expert knowledge upon the subject, by proofs they will offer and by the photographic illustrations which will be presently thrown upon the screen, if time permits.

With regard to the practical importance of the subject, I cannot do better than to quote from the admirable report of Chief Smoke Inspector Adams, of the city of Chicago, published in one of the reports of the Board of Health of that city.

Mr. Adams says:

"Viewed from the standpoint of the smoke inspector, the 1,600,000 people of Chicago are divided into two classes: (1) those who create a smoke nuisance; (2) those who are compelled to tolerate a smoke

nuisance. One class has radical champions, who maintain that smoke is an irrepressible necessity—a concomitant of the commercial and manufacturing supremacy of Chicago; that smoke not only is not unhealthy, but that it is an actual disinfectant; that the advocates of smoke abatement are visionary sentimentalists, and, in a general way, they are emphatically opposed to any agitation of the subject."

The inspector gives the other side also:

"They declare that the smoke nuisance is a positive menace to the health of citizens; that it has resulted in an alarming increase in throat, lung and eye diseases; they point to ruined carpets, paintings, fabrics, the soot-besmeared façades of buildings, and to a smoke-beclouded sky, and demand that the smoke inspector do his plain duty under the law."

The Chicago inspector gives some astonishing facts and valuable suggestions. He shows that within the corporate limits of the city there are located 15,000 steam boilers, of which not less than 12,000 are consumers of soft coal. These are scattered over 186 square miles, and no two plants are alike. He says:

"I know of an instance in which a restaurant firm so consumed $600 worth of coal as to cause an actual damage to adjacent property exceeding $25,000. In another instance, an apartment building, under the management of a receiver, protected by the court against the enforcement of the smoke ordinance, ruined the furniture and furnishings of every residence for two blocks in its neighborhood, and depreciated the value of adjacent real estate more than one-third of its former value. * * * Fortunately there exists a growing contingent around which is crystallizing a sentiment that it is practical and possible to abate the smoke nuisance without endangering the stupendous interests involved. The most intelligent and active members are drawn from the ranks of those formerly largely responsible for the smoke nuisance. They now oppose smoke for the same reason that they once defended it; they have made the discovery that it is cheaper to abate a smoke nuisance than to maintain one, and by reason thereof the smoke nuisance in Chicago will be a relic of the past before the close of the present century."

A few years ago the city of St. Louis appointed a committee of disinterested gentlemen (civil and mechanical engineers and others) to investigate the smoke nuisance, and their report is a valuable document, but limited time precludes any other reference thereto.

The problem of smoke prevention may be studied from several different points of view.

(1) The simplest and best solution is, undoubtedly, the use of smokeless fuel. Petroleum is an ideal smokeless fuel, and its qualifications were exploited at the Chicago Exposition, where a battery of boilers of 25,000 horse-power,

fed from fuel oil, piped all the way from Lima, O., excited admiration. The absence of smoke, dirt, ashes, economy, of labor, etc., and beauty of the installation, were the most plainly and conspicuously apparent features. Further examination revealed other merits, thus: 1 pound of petroleum evaporated 18½ pounds of water at 212° F., or more than twice as much as the average evaporation obtained from coal in ordinary boiler practice.

In Russia, where fuel oil is abundant, locomotives, steamships, stationary boilers and private dwellings use petroleum fuel almost exclusively.

In Chicago, upwards of 2,000 barrels of fuel oil are now consumed daily.

Several years ago the Pennsylvania Railroad investigated the subject of fuel oil for locomotives, and sent their chief chemist to Baku, Russia, to study the question at the place where such oil is most largely procured. On his return, this gentleman, Dr. Dudley, said in this hall:

"In the experiments already alluded to on the Pennsylvania Railroad, it was actually found, with oil at 30 cents per barrel, it cost nearly 50 per cent. more to take the same train of cars 100 miles by means of oil than by means of coal."

Dr. Dudley stated further that the oil production in this country was entirely inadequate to supply the place of coal for fuel. The total consumption of coal on the Pennsylvania Railroad, including all its ramifications, was, at that time (1888), about 8,000 tons per day. "If now," said Dr. Dudley, "this fuel consumption was changed from coal to oil, the Pennsylvania Railroad alone would use over 26,000 barrels of oil per day, and this 26,000 barrels is over one-third, and at the present time nearly one-half of the daily oil production of the United States; so that lack of supply, in this country at least, will, for a long time to come, prevent the use of oil in anything more than a very limited way. In Russia, no difficulty of this kind occurs, and for two reasons:

"First, because the oil supply is enormously greater than it is here. When I was in Russia it was credibly stated

that a new well had been struck, which actually flowed more per day than the total daily production of the United States.

"The second reason is that the nature of the Russian petroleum is entirely different from American. With the largest portion of American petroleum, 75 per cent. is capable of being made into refined oil, leaving 25 per cent. of residues. In Russia the figures are exactly reversed —25 per cent. only is made into refined oil, 75 per cent. is residues. These are what is burned. They have a fire test of about 320° to 340°, and look, and are, in truth, very much like our ordinary reduced petroleum, known in the market as 'well oil,' and used for lubrication."

Notwithstanding the fact that the Lima fuel-oil fields have been discovered since Dr. Dudley's address was delivered, events have proven the correctness of his predictions, and we may as well abandon the idea of the probability of the general use of petroleum as fuel in this country.

(2) The use of anthracite coal is too well known to require more than passing mention, but it is an unfortunate fact that this admirable fuel has proven unable to compete successfully with bituminous coal in the race for industrial supremacy, for several reasons. The anthracite coal belt is confined to Pennsylvania; the surface croppings have become exhausted, the veins have been followed deeper and deeper into the bowels of the earth, and the cost of mining is consequently constantly growing larger. Since 1880 the output of anthracite has doubled, but in the same time the production of bituminous coal has almost quadrupled, and new sources of supply of the latter fuel are being continually uncovered and developed all over the country.

In 1895 (the latest date for which I have obtained official data) the total output of coal in the United States reached the enormous amount of 172,426,366 long tons; the bituminous output was 120,641,244 tons, the anthracite production was 51,785,122 tons.

In 1880 the production was (in round figures): Bituminous, 38,000,000 tons; anthracite, 25,000,000 tons. Thus the anthracite output in 1895 was double the output in 1880,

while the production of bituminous coal was more than three times as great as in 1880.

In London and in our Western cities, where bituminous coal is used almost universally in households, the smoke-abatement question is much more difficult of solution than it is in Philadelphia, where anthracite is exclusively used (except in a few open grates) in families.

Since the disruption of the soft coal pool and consequent great reduction in price of bituminous coal,* many manufacturers in this city who formerly used anthracite—on account of the avoidance of smoke—have been compelled to change to bituminous fuel.

The last annual report of the United States Geological Survey (1895-96) contains a table showing the amount of anthracite and bituminous coal received, exported and used in Philadelphia in 1894 and 1895. This gives the "local" consumption of bituminous coal in those years as 845,000 tons and 1,060,000 tons, respectively, and of anthracite 3,540,000 tons and 3,960,000 tons.

Since the beginning of the present year the increase in the local use of bituminous coal has been most noticeable, for the reasons already given, and I heard, to-day, on reliable authority, of an instance where a single customer, a large concern in this city, which purchased of the Reading Coal and Iron Company 100,000 tons of anthracite last year, and approximate amounts in former years, has not bought any anthracite coal this year. The reason is obvious and the effect is also apparent.

(3) Smokeless combustion of bituminous coal.

It was my intention, if time had permitted, to illustrate my remarks with a simple, practical demonstration of the cause of black smoke production from distilling or imperfectly consuming bituminous coal, and to show methods of prevention of smoke, but, in view of the rapidly-passing time and

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* The *Railroad Gazette* of April 2d, referring to this matter, says: "It was a scramble for tonnage, in which prices had secondary consideration, and it is very difficult to quote prices to-day, as they are largely a matter of bargain. The nominal quotation is $1.90 at Norfolk, Newport News and Philadelphia, with 10 cents differential in favor of the Clearfield region."

of the number of speakers who are to follow me, I will not occupy more of your attention at present, but will close my address with the statement that the result of my own investigations of the subject of the smoke nuisance from burning bituminous coal is, that the problem of its abatement has been—in so far as relates to stationary boilers—practically solved, and that, in the present state of the mechanic arts, the emission of dense black smoke within city limits should not be permitted, because it can be practically and economically obviated.

DR. R. H. THURSTON [Correspondence]:—I have had very little to do in a business way with the matter which is here considered; but the subject is one of interest to every engineer, and I have, as a matter of course, studied it somewhat and, in the course of a now somewhat extended professional career, have seen something of the practical side of the economical question involved. It is, in fact, a matter largely of finance. The nuisance is certainly capable of substantial, if not of absolutely complete, abatement, as was shown a century ago by Watt, when he produced the first "down-draught" furnace, and by hundreds of others, up to the time of Charles Wye Williams, and later investigators who have experimented with various expedients involving the efficient use of the dead-plate, and the employment of specially arranged air-ducts, bringing fresh air into the furnace at a point at which the smoke, once formed, could be consumed, or, more correctly, I have no doubt, by which its formation could be prevented, by insuring the complete combustion of the bituminous fuel at the critical place and time.

The preventives which operate more or less effectively may be considered in the following order, viz.: Legislation, Skilful Operation of Furnaces, Special Constructions of Furnaces.

Legislation may be made effective, simply because it is actually practicable to-day to suppress the nuisance by means available to all. I am inclined to believe that the most effective form of legislation is that which operates through the Boards of Health of the cities. By this I do not

mean to intimate that the "smoke nuisance" endangers health in any ordinary case; on the contrary, I am inclined to think that the presence of this, which is always a minute amount of free carbon in the air, is rather healthful than otherwise; but it unquestionably is a nuisance, nevertheless, and possibly such healthful and aseptic influence as it has may be more than counteracted, in ultimate value, by the malign influence exerted on morals and manners, and against that cleanliness which is next to Godliness.

Boards of Health, however, seem to be the proper agencies through which to bring about this particular reform. There should be, in every city, municipal regulations compelling the officers of the municipality to keep constant supervision over this, as over all other nuisances, and to report every case of evident infraction of the law. Then, if, after ample warning, the nuisance is continued, the Boards of Health should be empowered to take steps toward the summary extinction of its source.

The fines inflicted, under the usual system of suppression, should be such as would make the employment of fuel in such manner as to produce notable amounts of smoke more costly than the use of smokeless fuels. Perhaps the most effective and simple system of fines would make the assessment a stated sum per month per square foot of grate-surface of boilers employed, and during the periods throughout which infraction of the regulations of the city can be proved. At 15 pounds burned per square foot of grate per hour, for a working year of 3,000 hours, about 2 tons of fuel will be consumed. The difference in costs of bituminous and anthracite coals being taken as, we will say, for illustration, $2 per ton, the proprietor can bear a tax of that amount, if it should prove necessary, on the part of the city, to impose it; and this means about $4 per annum per square foot of grate surface. A fine of 25 to 50 cents a month per square foot of offending grate will thus, presumably, abate the nuisance under such circumstances. Very likely a much smaller sum may prove sufficient; but that is a matter for trial, and one to be settled by experience.

In imposing fines, I should propose that they be gradually raised from some comparatively small minimum, by easy increments, to the maximum just indicated. Very probably a fine of 5 cents a month per square foot of grate, for cases reported, with publication of the reports in the daily press, would extinguish a considerable proportion of the smoke. Increase to 10 cents would reduce the offenders to comparatively small numbers; 20 cents might, perhaps, shut down substantially all of the well-disposed, leaving a few obstinate cases, or cases of peculiar difficulty from the standpoint of engineering, to pay the full cost of smokeless fuels until the changes required could be effected. So far as my own observation and experience go, this system of gradual extinction of the nuisance works by far best.

The methods of reduction of smoke are well understood by every member of the engineering profession familiar with steam-making practice. They all accomplish the result in substantially the same way—insuring ample air supply and amply high temperature for ignition at that point on the surface of the fuel bed at which decomposition, without ignition, would otherwise occur. Air supply in excess at the bridge-wall, or at some neighboring point, is a common expedient. The gradual coking of the fuel, when first thrown into the furnace, on a "dead-plate" near its mouth, is a practice as old probably as the steam engine. The recent forms of mechanical stokers seem to me, though not always successful, to be, in some cases, peculiarly well adapted to secure smokeless combustion. The "down-draught" furnace, invented by Watt, and improved in modern times and by contemporary inventors mainly, is one of the most interesting and curious of the later systems of combating this nuisance. There are now so many methods and so many forms of apparatus which are capable of more or less completely preventing smoke, that where there is a will, the only obstacle to success in finding the way lies in the financial aspect of the case. Both the methods and the apparatus needed are now available and well known.

In some of the Western cities, St. Louis notably, the success met with in the reduction of the smoke nuisance

has been most satisfactory and encouraging. I think that even the city of Pittsburgh is profiting by these modern ideas to some extent, for it is certainly not as smoky a city since its return to the use of coal as before it was blessed, temporarily, by ample supplies of natural gas.

The quantity of fuel lost in smoke is too small to make its reduction important as a matter of simple economy. Experiments in the Sibley College laboratories, about two years ago and since, have shown that, under the conditions of those experiments, at least, it was possible to produce, "deliberately and with malice prepense," the densest smoke being secured that was practicable, about 15 pounds of soot per ton of fuel employed. The usual figures for dense smoke ranged from 10 to 12 pounds. Of this soot about one-half was carbon, the remainder mainly unconsumed hydrocarbons, 10 to 15 per cent. of ash and, if collected outside the furnace, perhaps 2 per cent. of moisture.—Gilbert and Flory, in *The Sibley Journal of Engineering*, May, 1895.

It was found that no smoke was ever produced in an atmosphere of oxygen. With restricted air supply the maximum just stated was obtainable. Low temperature combustion and restricted oxygen supply seem to be the two main conditions favoring smoke production. Singularly, as it seemed to me, the composition of soot was found often to be substantially that of the coal from which it was produced. A reduction of the proportion of smoke made effects a reduction correspondingly, perhaps proportionately, in the percentage of carbon contained in the soot. Thus coal used at St. Louis was found to contain 50 per cent. carbon, 36 per cent. hydrocarbons. Its smoke contained 25 per cent. carbon and 10 per cent. hydrocarbons. Where no hydrocarbons exist, smoke cannot be produced by any fuel. It is evident that in the average case we cannot expect reduction of smoke to result in economy of fuel or of expenses. It will cost more to extinguish smoke in most cases probably than can be gained by its suppression and its utilization as fuel.

In Circular No. 7, of the Steam Users' Association, of Boston, the statement will be found, supported by evidence,

that "stokers" save smoke in all cases. The prime advantage of this system, as it relates to the reduction of waste by smoke and incomplete combustion, lies in the fact that, with continuous and steady operation, the adjustment of the air supply, the depth of the fuel bed, and, in fact, of all the variable conditions of combustion, become practicable, each being gradually brought to its best adjustment; and, finally, all conditions being made those of best effect and then so retained, without difficulty, in such manner as to insure the utmost possible efficiency. Where, as in ordinary hand-firing, the conditions of operation are never the same for five minutes at a time, it is evidently impossible to insure correct adjustments or conditions of maximum efficiency at any instant, much less to preserve them through the working day.

In firing anthracite on board ship—which happens to be the practice with which I have been specially and practically most familiar—I have found this to be the fact also, and the steadier the condition of operation the better the result. This maximum steadiness is, in this case, brought about by regular firing, and at rather frequent intervals, the furnace door being opened, by the attendant coal-passer or by a neighbor fireman, only during the instant that the shovelful of coal is going in and the fireman is getting his glance at the best spot for the next; thus preserving the intensity of the fire by thin firing and restricted influx of cold air, either through the door when firing or through holes in the fuel bed.

Precautions against reduction of the temperature of the furnace by too close contact with the comparatively cold surfaces of the boiler is, I think, sometimes a matter of more importance than is generally assumed or realized. Some constructions of the steam boiler, unsuccessful at first in a soft-coal market, have been made more successful, if not completely so, by enlarging the furnace-volume and by protecting the fuel-bed from loss of temperature by direct radiation, the protection being afforded more or less completely by brick arching and by lining.

The general principle governing this, as almost every other phase of boiler efficiency, may be stated to be:

Secure maximum temperature of furnace, producing the total heat of combustion, as nearly as practicable, before commencing to take off heat for application to steam-making. *First*, make the work of developing the heat of combustion perfect, *then* transfer that heat to the point at which it is to be used. Maximum temperature of furnace insures chemical union, if the combustible and the supporter of combustion are present in proper proportions, and the securing of proper proportions then becomes the one essential requirement for success.

I am inclined to expect highest efficiency, ultimately, through the use of the mechanical stoker, after "the survival of the fittest" shall have shown which of the many and ingenious existing forms is best suited to use with each of the type-fuels of the country.—[SIBLEY COLLEGE, CORNELL UNIVERSITY, April 19, 1897.]

MR. WILLIAM R. RONEY:—I appear before you to-night as a substitute for another speaker, who, being unable to come, asked me to take his place. Having but short notice, I fear I will not be able to add much to what has already been said, but will, however, venture a few remarks.

The production of smoke from bituminous coal is one of the results of imperfect combustion. That it should be prevented, no one will question; that it can be, few will doubt. The problem for the engineer and those connected with industrial interests to solve is, how to do this, and, at the same time, secure the highest economic results from the coal burned.

I hardly need state before an audience of this character that there are four requirements for complete or smokeless combustion, but to make my remarks better understood, I will name them, viz.:

(1) Sufficient air to supply the necessary oxygen.

(2) A thorough mingling of the oxygen with the volatile gases.

(3) A constant high temperature of air and gases; and

(4) A uniform supply of fuel, regulated according to the demands for heat for steam-making or other purposes.

If these conditions are present in the furnace, we have

complete combustion and no smoke. To accomplish all this is difficult with the ordinary hand-fired furnace and the average fireman, but with a good mechanical stoker and a fireman of ordinary intelligence, it can be accomplished and bituminous coal may be burned without smoke.

The first condition, namely, a sufficient air supply, is necessary for either flat grates or stokers, and requires a good draft, natural or artificial, which can be secured by a tall chimney properly proportioned, or by the use of mechanically induced draft apparatus.

The second condition of a thorough mingling of the air and volatile gases exists in a hand-fired furnace when the fire is new and clean, and the air can pass freely through the bed of burning coal, but after it has burnt a while the ash and clinker accumulates next to the grate from the constant spreading of fresh coal on top of the fire, and the quantity of air passing through the grate is very greatly lessened, and the economy also seriously affected. But with a mechanical stoker having moving grates, the contrary is true, as the motion of the grate bars keeps the fire clean and open and permits a constant and free circulation of air.

The third condition, namely, a constant high temperature of the air and gases, cannot be obtained with a hand-fired furnace, as the frequent opening of doors for cleaning and firing causes an inrush of cold air, which quickly lowers the temperature of the furnace below that required for the ignition of the gases—about 1,000° Fahr.—and the carbon is precipitated in the form of finely divided particles of soot, which roll out the chimney as smoke. On the other hand, a mechanical stoker, properly designed, can be operated continuously without the opening of doors, and the initial temperature in the furnace maintained at as high a point as is necessary for perfect combustion. Mechanical stokers have been applied to reheating furnaces in rolling mills, and a temperature of over 3,000° Fahr. has been maintained for many hours at a time.

The fourth condition of a uniform supply of fuel is equally as important as the other three. Here is where the mechanical stoker is especially successful. The average

hand-fireman fires in the way that he thinks will be easiest, which generally consists in piling in the coal until the furnace will hold no more, and then sitting down and letting it smoke. Even with skilful hand-firing, the supply of coal is necessarily intermittent. It is, of course, possible to fire by hand and produce practically no smoke, by firing often and in very small quantities; but this is hard work and requires intelligence, and it is not easy to find men who will do it for the average fireman's wages. If they have the necessary brains, they will not stay in the boiler room, but will seek a more desirable place and better pay. The result is that, as a rule, we have a very inferior class of men in the boiler rooms, and it is not strange that the results of average hand-firing are so unsatisfactory, both in economy and smokelessness.

A mechanical stoker of simple design, operated by the ordinary fireman, will give a uniformity in fuel supply and freedom from smoke unattainable by the most skilful hand-firing; and with the proper draft will develop a large increase in capacity over hand-firing, and do so without smoke. The forcing of hand-fired boilers is a prolific source of smoke, as to do this requires frequent slicing and stirring, causing large quantities of the volatile gases to escape up the chimney unburned, to pollute the atmosphere and reduce the profits of the man who pays the coal bills. This nuisance and loss can be prevented, and I believe mechanical stokers are the surest means for accomplishing it.

Another cause of smoke is the fact that very few boilers have sufficient room for the combustion of the gases from bituminous coal. Many boilers are set so low that almost as soon as the gases are released from the coal, they impinge on the cold shell of the boiler, lose their heat and pass up the chimney as smoke. Great numbers of boilers were originally set to burn anthracite coal, and when the change was made to bituminous, no change was made in the setting which provides less than one-third the combustion room required by bituminous coal. This is a very common fault with boilers in New England, where, up to a few years ago, anthracite coal was burned almost entirely. This

difficulty is completely overcome by mechanical stokers of the inclined grate type, as the large combustion chamber, combined with the uniform supply of coal and the gradual distillation of the gases in the coolest part of the furnace, presents conditions most favorable for complete and smokeless combustion.

If you wish to secure the co-operation of those who burn bituminous coal, and to enlist them on the side of smoke prevention, you must be able to show them that the saving in fuel will justify the cost of apparatus to prevent smoke.

The loss in fuel by the production of smoke, is principally due to the invisible gases which escape up the chimney unconsumed, and which, together with the carbon in the smoke, frequently represent a large percentage of the heat value of the coal. I have done considerable engineering in connection with mechanical stokers during the past twelve years, and know, from observation and experience, that they will not only give smokeless combustion, but effect a saving in fuel and labor which will pay a large percentage on their cost. They will save in fuel 10 per cent. and upwards over average hand-firing, which, at the present price of coal in Philadelphia, is fully 25 per cent. on the cost of the stokers. Where the plants are large enough to require more than one fireman, there will be an additional saving in labor.

If such facts are properly presented to those who are making smoke, it seems to me that there should be but little difficulty in convincing them that it is for their interest financially, to say nothing of their civic pride, that they use well-known and proven means to abate the smoke nuisance in this city.

PROF. L. M. HAUPT [Correspondence]:—In response to your suggestion that I would contribute to the discussion of the smoke nuisance question, I would submit that, as the unconsumed carbon is simply waste, it would be to the interest of all parties to prevent its escape. This can be largely effected by more intelligent firing, whereby a larger amount of oxygen is admitted over the incandescent

material, instead of being forced through it. This was very forcibly impressed on me whilst riding on an engine in Ireland, where the fireman fed his fuel in small quantities well distributed and left the upper door ajar. We made 60 miles an hour with a heavy train, and only a thin white smoke was emitted from the stack.

I have requested Col. Thos. P. Roberts, of Pittsburgh, to give his experience, and have received from him some printed data (sent herewith) which will prove of interest in the discussion of this important subject.—No 18 South Broad Street, Phila., April 15, 1897.

Thomas P. Roberts (Correspondence):—I am in receipt of your letter of the 10th inst., asking for my views as to the smoke abatement question in Pittsburgh, and especially with reference to the effect of the city ordinance bearing on the subject.

This is a matter to which, several years ago, I gave considerable personal attention, from the fact of having served on committees of the Engineers' Society of Western Pennsylvania and of the Chamber of Commerce, to which the subject had been relegated. For the last four years, however, I have had time only to be a casual observer of the progress that is being made, and, very often, I have been in the predicament of wondering how any real progress in smoke abatement was being made, while, monthly, there was a palpable increase in the visible supply. This is not a paradox, however, when all the facts are considered. On this point, however, I believe I can safely say that we have passed the maximum point of the smoke nuisance in Pittsburgh, and, like the National pension list, it must continue henceforward to decline, and ultimately to disappear.

Pittsburgh, before the days of natural gas, *i. e.*, prior to 1883, was the very lions' den of smoke. Our people had become so accustomed to it as actually to take some solace to themselves from the statement of English travellers, which accorded us the palm even over London. Rarely, indeed, in those days were the hills across the Monongahela River visible from Water Street, one-third of a mile distant, and vegetable life beyond the ailanthus tree struggled in

vain as a beautifier of our streets. With the introduction, about 1883, of natural gas, an impetus was given to the sun-worshippers, and their doctrine of light and cleanliness spread with remarkable rapidity. For several years it was possible, from the roofs of the taller buildings, to look over the entire commercial part of the city, and see not a vestige of smoke, and, generally speaking, the atmosphere was as clear as it ever was over Boston, New York or Philadelphia.

With the decline in the yield of the gas wells and the return to the use of bituminous coal under boiler fires, organized efforts were made to have introduced in Pittsburgh, as far as practicable, smoke-consuming devices. The Engineers' Society, the Chamber of Commerce, and several ladies' organizations, became very energetic in this work, and finally their efforts resulted, in 1895, in the passage of the city ordinance. This ordinance* is, however, almost

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* AN ORDINANCE—No. 1263—To regulate and suppress the production and emission of smoke from bituminous coal, and to provide penalties for the violation thereof in the city of Pittsburgh. Approved May 22, 1895.

SECTION 1. *Be it ordained and enacted by the City of Pittsburgh, in Select and Common Councils assembled, and it is hereby ordained and enacted by the authority of the same, that* on and after October 1, 1895, the emission of more than 20 per cent. of Black or dark Gray smoke from any chimney or smoke-stack where bituminous coal is used as fuel in connection with boilers for heating and power purposes, shall be deemed and is hereby declared to be a public nuisance.

SEC. 2. That it shall be unlawful for any Corporation, Copartnership or Individual owning, controlling or using any chimney or smoke-stack used in connection with boilers within the city limits as provided in Section 1, to allow, suffer or permit smoke from bituminous coal to be emitted or to escape therefrom.

SEC. 3. Any Corporation, Copartnership or Individual who shall or may allow, suffer or permit smoke from bituminous coal to be emitted or to escape from any chimney or smoke-stack used in connection with boilers for over three minutes' duration at any one time, shall, in addition to any and all laws requiring the abatement of nuisances, forfeit and pay to the City of Pittsburgh for every such offence, a sum not less than ten ($10) dollars or more than fifty ($50) dollars to be recovered before any Alderman of the County of Allegheny or any Police Magistrate of the City of Pittsburgh as debts of like amounts are now recoverable.

SEC. 4. No discrimination shall be made against any device or method which may be used which will accomplish the purpose of this ordinance in relation to the said matter.

as smoky and obscure as the subject to which it relates. Sections 1, 2 and 3 conflict with themselves, and altogether, it is so illy constructed that it may be doubted whether there could be any successful prosecutions under its terms. The councils of no manufacturing city would be wise in entering too boldly upon such a field as this. If the edict reads "let there be no smoke," at least practicable means should be pointed out how to maintain fires without its production. The lack of precision and general weakness of the ordinance may, after all, have been for the best. There has never been a desire to employ unduly oppressive measures against offenders in Pittsburgh, and it has rather been the policy of the Department of Public Works, which has the enforcement of the ordinance in charge, to be as lenient as possible, and, through educational work and experiments at the pumping stations, to demonstrate that fuel bills might be reduced by proper methods of smoke consumption. Thus it is just now that Pittsburgh is a permanent exposition of smoke-consuming devices.

After two years' experience, a disposition has, at last, been manifested to take further and rather more stringent steps in the direction of a more decided reform. It is felt, however, that State legislation is necessary before any more decided movement is inaugurated; but in what way State laws are to be invoked, I am not, at present, informed.

I called at the Department yesterday, and had a brief talk with some of the officials, and was greatly pleased with what I learned, and I would advise the Franklin Institute to send a representative, or a committee, to Pittsburgh, and learn what has been accomplished by the smoke inspector and his two assistants. Here, also, examples of all the best, as well also of some of the worst, smoke-consuming devices could be examined, and I have no doubt that the officials in the Department at City Hall would extend every facility to inquiring visitors.

SEC. 5. The Director of the Department of Public Works of the City of Pittsburgh is hereby empowered and directed to enforce the provisions of this ordinance.

SEC. 6. That any Ordinance or part of Ordinance conflicting with the provisions of this Ordinance be and the same is hereby repealed so far as the same affects this Ordinance.

The Pittsburgh ordinance applies only to boilers used for heating and power purposes. The day for consumption of smoke from domestic fires has not yet arrived, not because the demand for it is weak, but simply because of the fact that no universally applicable system or device for its consumption has yet appeared.

I understand that about 400 firms or establishments have already complied with the law in Pittsburgh, either in whole or in part. In office buildings, the Roney, the American and Brightman stokers are chiefly used, while some of the large street-car line power-houses use the Murphy stoker. In one of the largest steel works, where 20,000 horse-power is developed and 114 steam boilers are in use, about 70 of the boilers are now equipped with the Black Diamond stoker, and the firm is so much pleased with them that they are about to place them under all their boilers.

I have very frequently seen, most excellent—I may say magical—results from the simple use of steam jets in the abatement of smoke. From some inquiry as to late experience I am led to believe that, when properly applied, steam jets are a positive and certain cure for even the smokiest of fires. There are situations where, from cramped positions, as in basements of buildings, and inefficiency in size of boilers, not sufficient draft can be secured for complete combustion, steam jets would do the work where no form of mechanical stoker would give satisfaction. A friend who has studied the matter, himself a former engineer in the U. S. Navy, states his belief that the use of steam jets is in no way injurious to boiler sheets, a point concerning which I had some apprehension. They were not, however, in his opinion, economical, *i. e.*, they were not coal savers, but ordinarily did not increase the consumption of the fuel over ordinary hand-stoking. Their lack in economy was more than compensated for, according to my friend, in the greater reliability and efficiency of the boilers in rapid steam production. I was told of a case in this city, where a 65 horse-power boiler was worked to 250 horse-power, yet with steam jets it produced little or no smoke. Much appears to depend upon the angle with

which the steam jets are set. The best practice here, I was told, was to arrange the jets about a foot apart, the orifices being $\frac{1}{32}$ of an inch in diameter.

The great trouble in Pittsburgh, and I suppose the same is true in other cities, is that the boilers are too frequently overtaxed. Architects are, also, much to blame for providing such scanty room for boilers in buildings. In fact, the boilers are generally placed in the very darkest corners, in places the owners seldom care to visit—and would see little if they did visit. To manage the boilers, an "engineer" (heaven save the mark) is engaged at wages that, with difficulty, will keep him alive. It has been asserted here by steam experts that men can be produced in Pittsburgh who will manage certain batteries of boilers with hand-stoking, guaranteeing to show up clean "smoke shade" cards, and who would accept for their pay the monthly saving in coal bills they could effect. But it appears that even capital and brains, as well as labor, run in such ruts that nothing startling is ever tried. The abatement of smoke seems to be especially one of these matters of public interest where everybody is hopeful regarding its future, but where everything drifts slowly. No matter how much we may wish for a revolution here, it will come only through the slower process which the omission of one letter of the word makes, viz.: evolution.—PITTSBURGH, PA., April 13, 1897.

D. ASHWORTH & SON, Pittsburgh, Pa. [Correspondence]:—In compliance with the request of your Secretary, we would present for your discussion of "The Smoke Nuisance and its Abatement," with special reference to your city, a few observations that we have noted from the practice in the West.

The subject of smoke prevention (or, more correctly speaking, smoke abatement) is one that has elicited much discussion and the earnest consideration of engineers, as well as those whose interests are in the commercial industries that suffer most from the growing evils in this direction.

In large cities the difficulties encountered by the engineer who endeavors to abate the smoke nuisance in an old

plant lie principally in the cramped condition of the boiler-room and the lack of provisions by architects for the increase in boiler plants. Not only do we find this condition presenting itself in old plants, but the oft-repeated lesson is disregarded by many architects, and we may find to-day many buildings under erection where no means is left for the enlargement of the power plant.

The loss of power which is attendant on the application of such furnaces as involve the use of steam jets is a serious consideration to plants that are running on the very margin of their utmost capacity. We are aware that many companies present tests showing an increased efficiency due to furnaces of this type; but in no test thus presented to us for consideration, nor in many tests that have been published, have the engineers deducted the amount of water that should be charged to the furnaces. We know this to be an important item from comparative tests we have made, in which the steam supplied to jets has been supplied from another source than the boilers under test, and in which the results have shown a marked decrease in the efficiency of the boiler.

Mechanical stoking, if intelligently handled, will aid greatly in abating the smoke evil. Some stokers will aid the plants that are running at their maximum; but in installing new furnaces under old boilers, from lack of careful study of local conditions, the results are more often of a disappointing nature.

Numerous devices, such as water arch, brick arches, the admission of air at the bridge-wall, etc., have made good records as smoke abaters; but with any of these it may safely be said that without careful firemen, of sufficient intelligence to study their fires and conditions, satisfactory results cannot be obtained. We cannot lay too much stress upon the importance of intelligent firemen, and for the fact that there are so many men firing boilers with no other thought than to shovel in coal, the responsibility lies with the lack of appreciation of their employers, who are of the opinion that any laborer can shovel coal, and remunerate him accordingly.

When the subject of smoke abatement has provoked sufficient interest as to warrant legislation, it is to be hoped that the matter will be placed in the hands of engineers who are competent to aid and instruct the people who are offending, by pointing out ways in which they may improve their plants, and not in the hands of clerks with the idea that any one can tell when a stack smokes. This is not what they need. What they require is an honest, unbiased engineer, who can show them that the stack not only smokes, but why it smokes, and how to stop it. Some cities have such men, but others are not so fortunate.

We are firmly convinced that great strides may be made in Philadelphia in the way of smoke abatement, without imposing burdensome restrictions upon commercial interests and that the results that will accrue will greatly benefit the city.

MR. EDWARD LONGSTRETH [Correspondence]:—In reply to an invitation to contribute to the discussion of the smoke nuisance question, I beg to submit as the expression of my opinion, a communication which I addressed, on March 18, 1891, to a committee of the Councils of the city of Philadelphia, viz.:

"Having been asked if the black smoke coming from locomotives by the use of soft or bituminous coal can be burned, I would say, do not make it, but burn the particles of carbon as soon as they come in contact with the fire. This can be done with a little care on the part of the fireman; he must keep a thin, bright fire, and scatter the coal as it leaves the shovel over the fire, and fire often, then very little smoke will be seen.

"Distilling smoke from coal and throwing it into the air is a great waste of fuel, as the black smoke is carbon—the most valuable part of the coal. The way to make an engine smoke is to fill the fire-box full with coal, and then let the fireman sit in the cab for the next half hour, then fill up and smoke again. Smoke from an engine is due to careless or ignorant firing. Thirty years ago, when they changed from burning wood to coal on locomotives, I had a great deal to do with numerous devices pat-

ented to consume smoke, but they soon passed out of existence, as it was found the plain fire-box with brick arch and a good fireman showed less smoke than the best patented boilers fired with a bad fireman.

"Watch the trains and you will often see one section not showing smoke, and perhaps with the next section of the same train the locomotive will fill the neighborhood with black smoke, the engines being the same and burning the same coal, but one having a better fireman than the other. In England they fine the engineer and fireman for carelessness if they let an engine smoke.

"The engines are all right (if they tear up a light fire, put in larger exhaust nozzles); educate the fireman and see that he does his duty, then the road will be richer and the neighbors happier."

In confirmation of the opinion stated in the foregoing, I would draw attention to the following communication, which appeared in the *Chicago Herald* of May 18, 1892, and which is self-explanatory, viz.:

"The warning recently given the railroad companies that they would be prosecuted for maintaining a smoke nuisance, if they did not apply some smoke-preventing device to their locomotives in 100 days, is having a salutary effect. The Michigan Central Railroad has 45 locomotives and switch engines in use on its Western Division. All except 8 of these are producing no smoke.

"The company spent thousands of dollars in testing patented devices, but found the best success at last in the use of unpatented air, introduced to the fire-box in a very simple manner. It comes so near preventing all smoke that the company is in no danger of prosecution or excoriation.

"The fact that a great railroad corporation will unbend sufficiently to abolish an offence to the public without compulsion is noteworthy, and the spirit in which this particular nuisance has been abated is commendable. The example may well be followed by owners of stationary engines, with which the problem of the smoke nuisance is much more easily solved. If every man were willing to

prevent smoke, half the battle against the nuisance would be over at once."—PHILADELPHIA, April 20, 1897.

MR. SAMUEL M. VAUCLAIN:—I did not come prepared to speak at length upon this subject, and have arranged no data for the purpose. The Baldwin Locomotive Works, however, with which I am connected, is one of the largest consumers of coal in this city. Several years ago we used, principally, the best grades of anthracite coal for steam-making and furnace purposes. We not only have stationary boilers furnishing steam for operating our plant, but we have, as well, large heating furnaces requiring a very high temperature, and also cupolas for the melting of irons. It became necessary, on account of the enormous outlay that we were making for fuel, to endeavor, if possible, to effect some economy in that direction, so as to reduce our running expenses; and we very naturally turned to the use of bituminous coal. We used a great deal of bituminous coal, which was well suited to the boilers and furnaces, as we had them in operation at the time.

The result of this change, however, was not a satisfactory one so far as the dirt and smoke and consequent nuisance to the neighborhood were concerned. The financial result, however, was very satisfactory. Our boilers were not adapted to the economic burning of refuse anthracite coal, and, in order to abate the smoke nuisance and effect a still further economy in our expenditure for fuel, we decided to use the low grades of anthracite buckwheat coal which were being put upon the market at that time.

In order to do this, we threw out our entire plant of boilers, some of which had given us long years of service, and we could very well afford to dispense with them, substituting in their place the most modern types of water-tube boilers, all fitted with first-class automatic stokers for the mechanical firing of the fuel.

The adoption of automatic stokers was made in order to save a large portion of the labor then employed in firing our boilers by hand, and also to effect a more thorough combustion and more thorough consumption of the fuel as it passed from the bins to the grates and from the grates to

the ash-pans. As an instance of this, one battery of boilers that we have in service—of 1,600 horse-power—requires but one fireman and a cleaner. The fireman's duties are to see that the stokers are always working properly, and that the water is fed to the boilers in a proper manner. The duties of the cleaner are to keep the place clean and polish up the bright work and see that the paint work is kept in order at all times. Both of these men have a very easy and comfortable time, and the steam is furnished at the minimum cost for fuel and absolutely without smoke.

At the present prices at which bituminous and anthracite buckwheat coal are sold in the city, we are able to effect a slight economy by the use of this class of fuel over the use of bituminous coal; in other words, we get more work from a dollar's worth of anthracite than from a dollar's worth of bituminous coal.

In our heating furnaces, an attempt to use the bituminous coal gave us very unsatisfactory results, so far as cleanliness and annoyance to our neighbors were concerned. It soon became evident that to continue the use of soft coal would not only call forth the protests of our immediate neighbors but also the opposition of the city fathers.

The idea then occurred to me that if we could mix that fuel with other fuel in some manner that would permit it to stand open—in other words, separate the particles of fuel so that the air could get at it properly—we would get more nearly perfect combustion with much less discharge of smoke.

The experiment was made by mixing 50 per cent. of anthracite pea coal with the bituminous coal, and the result was very satisfactory indeed, causing an almost entire cessation of the smoke from these furnaces, of which we have a great number congregated together in a very small area. We have been following this practice now for several years with great satisfaction, and have not only, as I have said, avoided nearly all of the smoke nuisance, but have also effected quite a marked economy. It is, therefore, evident that, with ordinary care and judgment, soft

coal can be satisfactorily used by mixing it with anthracite coal, and nearly all of the smoke avoided.

In regard to locomotives, to which you no doubt expect me to refer in my remarks, I beg to say that this is quite another question. The consumption of anthracite coal, of course, produces no smoke, but whether bituminous coal can be burned in a locomotive fire-box without making smoke is, of course, the important question to be decided. It is a very easy matter for one to say that this can be accomplished by careful firing, and opening of the fire-door, and in various other methods heretofore alluded to.

In my opinion, however, the question of satisfactorily avoiding the smoke from locomotives depends upon the amount of coal that it is required of the locomotive to consume per square foot of grate surface every hour. If the locomotive is so constructed that this amount is excessively high, it is impossible to avoid the making of smoke, which occurs from incomplete combustion. Forced firing on a locomotive is not only hard on the fireman himself, but on the bank account as well, as the evaporative efficiency of the fuel is very much reduced, and, consequently, the objectionable emissions from the smoke-stack are very great.

Of late years, the practice at the Baldwin Locomotive Works, where we design locomotives for burning all grades of fuel, has been to have samples of the coal, which is intended to be burned in the locomotives, submitted to us. We carefully analyze this fuel, and then decide as to the proper dimensions for the fire-box, and provisions for the admission of air over the fire, so as to avoid, as far as possible, the emission of black smoke; or, in other words, to arrive at as near perfect combustion as it is possible for us to do.

The personal equation, however, on a locomotive, is a somewhat large one. The fact that one locomotive will make no smoke in starting a train out of a station and passing through the suburbs of the town, and that another of the same class and type, immediately following, will emit

great volumes of black smoke, is sometimes due to the fact that the second engine has been hurriedly called upon to do this service, and the fireman has not had sufficient time, to use a common expression, to "burn a good fire," or, in other words, to get his fire in proper shape before leaving the station. If the fire be in proper condition before he leaves the station, he will have no occasion to put large quantities of fuel in the fire-box until after the city limits have been passed, but if the fire has not been properly prepared, he must get to work at once to furnish his fire with fuel and build it up; otherwise, the fire that he had when he started will be destroyed by the action of the engine, and it will be rendered practically unfit for service, or at least to maintain its schedule speed until he has had an opportunity to recover the fire and get it in good shape. It is, therefore, very easily understood why in some instances a great deal of supposedly unnecessary black smoke is made in starting trains.

The chief qualification necessary in a locomotive for burning bituminous coal is to have a sufficiently large grate area to give an economical coal consumption per square foot of grate surface per hour. This condition is found in what is known as the Wootten boiler, or Wootten fire-box, as now used by a great many of our leading railroads for burning refuse coal of all grades. At the present time we are changing twenty-five narrow fire-box locomotives and fitting them with Wootten boilers, or fire-boxes, for this purpose, for the Erie Railroad. The successful burning of bituminous coal in these engines is, of course, obtained by exercising some judgment in their manipulation, and their chief advantages are their very large grate surface and combustion chamber, and the ready facilities for admitting air over the top of the fire, permitting it to combine with the smoke as it arises from the surface of the fire, and to consume it in the combustion chamber before it passes out through the stack. We have built engines of this sort for burning the very poorest quality of bituminous coal, or bituminous slack refuse from the mines, having from 35 to

40 per cent. of ash in it, and the engines are giving the greatest satisfaction.

I beg to say, in concluding, that, judging from the experience of the preceding speaker, we are to believe that the consumption of petroleum as fuel under steam boilers is attended with considerable smoke until the furnaces, which are firebrick, have become incandescent. While this is, no doubt, true of the cases cited by the speaker, we do not find it the case in locomotives, as we have built very large numbers of locomotives for burning petroleum, and we find that we never have any annoyance from smoke; that if the fireman is at all careful and attends to his business, the locomotive can be operated under all conditions and at all times without making any smoke or dirt whatever. This experience is not obtained merely by my own experiments between Baltimore and Jersey City, but is the experience of all our engineers returning from Russia, for which country we have built large numbers of oil-burning engines, and where oil is the fuel for generating steam in almost all cases; and its use is absolutely smokeless.

I neglected to say that for culinary purposes, or domestic use, the bituminous coal could be coked at the mines and used in that shape if it becomes necessary to avoid the smoke from this source. Railroad lines running into Philadelphia have resorted to the use of coke for fuel for their best trains to avoid the smoke due to the use of bituminous coal, and I wish to say that it is perfectly practicable to use coke as fuel in all of the various types of bituminous-burning engines as constructed at the present time.

MR. JAMES CHRISTIE:—It may serve to demonstrate how slowly permanent progress is made, if we reflect on the fact that the subject under discussion this evening has been actively agitated for over a century; for it is over one hundred years since James Watt burnt bituminous coal, without smoke, by means of his dead plate or retort-mouth in front of a fire-grate, and since Benjamin Franklin exhibited his revolving or barrel grate, as just described to us. Some may further wonder what interest Philadelphia has in the

subject, situated as she is so close to the anthracite fields. But as we find that bituminous coal is now delivered here at a lower price than anthracite of buckwheat size, and that the calorific power of the former substantially exceeds the latter, we are forced to the conclusion that the subject of smoke prevention is now at hand.

It has long been well known that if the first products evolved from coal were passed through a mass of incandescent fuel, a smokeless flame was readily obtained. Consequently, the annals of invention are replete with devices to accomplish combustion in this way.

The coal has been pushed up from beneath—keeping the incandescent mass on top—constituting the so-called under-fed methods; the coal has been heaped on top, but the draft acting downwards, forming the down-draft systems, and the coal has been pushed in horizontally and the incandescent mass kept in front of it. This latter is the usual system with the mechanical stokers of to-day, and excellent results are obtained for steam boilers and similar purposes. The down-draft system also gives good results when properly applied, but I know of none of the under-fed systems which have endured.

I had the opportunity, thirty years ago, to experiment on a very ingenious adaptation of the under-fed system, but soon found that its inherent defect was a tendency to push the ashes and incombustible constituents of the fuel into the burning mass, and, unless the fuel was exceptionally pure, the fire was rapidly fouled.

In many furnaces wherein metallurgical and similar operations are conducted, it is essential that no uncombined oxygen shall pass through the furnace; consequently, there will be some smoke emitted even when regenerative furnaces and producer gas are employed. Also, none of the smoke-preventing methods proposed have been thoroughly effective in the case of domestic stoves and grates, and the smoke emitted from these is large in the aggregate in districts where bituminous coal is the principal fuel.

Experience has shown it to be a very difficult subject

to control by legislation. More can be done by sanitary officials whose action is suggestive and advisory rather than harsh and repressive.

MR. MAX LIVINGSTONE:—So much has been presented this evening about the subject under discussion, that I can only add, referring especially to petroleum, that while it is, as Mr. Outerbridge has said, the ideal fuel, we can scarcely look for its general introduction, as the present production would fall considerably short of the demand.

But it is not with the "ideal fuel" that we have to deal this evening. Our consideration has to be given to fuel responsible for the smoke nuisance, and for its abatement we have to look to the, I might say, classical ground of England, where, by force of circumstances, every effort has to be used to suppress the annoyance. The late hour, however, does not permit a discussion in detail this evening.

[Owing to the lateness of the hour, and as a number of intending participants had been unable to express their views on the subject, it was decided to continue the discussion at the next stated meeting, Wednesday, May 19, 1897.—W.]

THE TIN PLATE INDUSTRY IN THE UNITED STATES.*

BY COLONEL IRA AYER,

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The tin plate industry dates its birth, and the conditions which resulted in its steady and rapid growth and permanent establishment in the United States, from the passage of the Tariff Act of October 1, 1890, commonly known and referred to as the McKinley Law.

Prior to that time, viz.: in 1873, a few plates were made by a firm at Wellsville, O., and by one at Leechburg, Pa., but both enterprises proving unprofitable, in 1875 they were discontinued. About that time works were built and opera-

* A lecture delivered before the Franklin Institute, March 5, 1897.

tions begun at Demmler, near Pittsburgh, Pa. The ruling price of tin plates was then so high as to afford a large margin of profit to Welsh manufacturers, but as they practically had no competition they fixed their own price to the American consumer. If these prices had continued, domestic plates would probably have been able to hold their own against the competition of foreign plates, but such was not the case. As soon as it became evident to Welsh manufacturers that American firms were liable to become formidable competitors, they began to reduce their prices until, in 1879, the price was so low that the Demmler works closed, it being impossible, under the existing conditions, to continue the manufacture without loss, and were not reopened for the manufacture of tin plates until the passage of the McKinley Law in 1890, a period having elapsed of from eleven to twelve years.

Under the provisions of the McKinley Law a duty was imposed on tin and terne plates of 2·2 cents per pound, a duty which it was believed would afford ample protection to American manufacturers, and would result in the establishment of the industry in this country.

That such was the belief and the intention of Congress will be apparent by a brief consideration of the provisions of paragraph 143 of the Act, which required, in substance, that during one of the six fiscal years beginning July 1, 1891, and ending June 30, 1897, the total production of tin and terne plates in the United States, weighing lighter than 63 pounds per 100 square feet, should, as a condition of the continuance of the duty of 2·2 cents per pound as provided, equal one-third the amount of such plates imported and entered for consumption in any one of the said fiscal years; otherwise, on and after October 1, 1897, all such plates should be admitted free of duty.

In the same connection it was provided that the amount of such plates manufactured into articles exported, and upon which a drawback of the duties should be paid, should not be included in ascertaining the amount of such importations.

It was further provided that the amount or weight of

sheet iron or sheet steel manufactured in the United States, and applied or wrought in the manufacture of articles or wares tinned or terne-plated in the United States, with weight allowance as sold to manufacturers or others, should be considered as tin and terne plates produced in the United States within the meaning of the Act.

The exact bearing of these provisions will, perhaps, be more clear by a few words of explanation.

First, then, tin plates are sheets of iron or steel coated with tin. They are used in making many kinds of domestic utensils, also in the manufacture of cans for the preservation of fruits and vegetables, and for many other purposes, which will be readily recalled.

Terne plates are sheets of iron or steel coated with an alloy of tin and lead, the proportion of tin being usually from 10 per cent. to 30 per cent. Terne plates are generally used for roofing purposes, and are hence sometimes called roofing plates.

Plates weighing lighter than 63 pounds per 100 square feet are what are known in commerce as I C plates and I X plates, which are so thin, or of so light a make, as to be suitable for manufacture into tin cans. The provision removing the duty on this class of plates on and after October 1, 1897, in case the prescribed conditions of manufacture had not been met by American manufacturers, was intended particularly as a concession to the canning industries, whose business would presumably be interfered with for a time, by the increased price of tin plates, growing out of the increased rate of duty, the increase being 1·2 cents per pound more than was provided by the previous tariff.

In view of the provisions of law cited, and which I have endeavored to make clear, it became necessary for the Government to procure correct statistics:

(1) Of the aggregate production in the United States of tin and terne plates, weighing lighter than 63 pounds per 100 square feet, during each of the six fiscal years named in the act.

(2) The amount or weight of sheet iron or sheet steel manufactured in the United States, and applied or wrought

in the manufacture of articles or wares, tinned or terne-plated in the United States, with weight allowance as sold to manufacturers or others, for each of the said years.

(3) The total importations and exportations with benefit of drawback of all such plates during each of the fiscal years covering the same period.

Under a ruling of the department, the coating of metal sheets, or "black plates," as they are called, whether of American or foreign manufacture, with a tin or terne coating, constituted a manufacture of American tin plates within the meaning of the law.

It has been held, without question, that the tin used for coating the plates may be either of American or foreign production. On the other hand, with respect to the sheet iron or steel, applied or wrought in the manufacture of articles or wares, tinned or terne-plated in the United States, the department rigidly held that they must be of American production, as the law explicity refers to "sheet iron or sheet steel manufactured in the United States." It was not understood that the limitation relative to minimum weight applied to these last-named manufactures, the last proviso of paragraph 143 being silent upon that point.

It was in October, 1891, some fcur months after the tin plate provision of the law went into effect, that I received my instructions from the Treasury Department to collect and formulate these statistics, and put them in the form of a permanent record at Washington for the information of the administrative officers of the Government. At that time there was a strong feeling against many of the provisions of the McKinley law, and against the tin plate provision the feeling was especially strong.

It was persistently denied that tin plates were being made in this country, the industry was belittled and American manufacturers were held up to scorn and ridicule. The importing interests, represented largely by the agents of foreign manufacturers, were exceedingly hostile, and, owing largely to their representations, there was a widespread belief that tin plates could not be made in the United States. Even friends of the industry shared this belief, or at least were

the subjects of doubt and misgivings. Probably nothing of the kind was ever so little understood, or so much attracted public attention and awakened so deep an interest. Many were ignorant as to what tin plates and terne plates really were. The question was not infrequently asked if we "were producing any *tin* in this country," the presumption being that unless we had tin mines and could mine tin successfully, the industry must prove a failure. It was not generally understood that much of the tin used by British manufacturers for coating their plates was obtained from the East Indies and other countries, and that those sources of supply were open to us as well as to them.

Under these circumstances, one of the first thoughts that occurred to me on receipt of my instructions was that, amidst all the contention and misapprehension upon the subject, the country would at last be placed in possession of the facts.

The necessary books were prepared for the use of manufacturers, in which to keep a daily record of their production, and it was arranged that each should make a sworn return of his production at the end of each quarter. Blanks were prepared and furnished to manufacturers for this purpose, and while the law was in force, not a single return was accepted that was not in proper form and duly sworn to. These blanks were made to show, separately, the production of tin and terne plates, both of the lighter and the heavier class, that is to say, lighter than 63 pounds per 100 square feet, and 63 pounds per 100 square feet and heavier. They were also made to show the quantity of plates made from American-rolled black plates, and the quantity from foreign plates.

Circular instructions were issued to manufacturers by the department, setting forth what would be required of them under the law, one set of instructions and blanks being for the guidance and use of manufacturers of commercial tin and terne plates, and another for the guidance and use of stamping or other manufacturing companies, using American sheet iron or steel for stamping or making into articles and wares, that were tinned or terne-plated after being formed.

Collectors of customs at the importing and exporting ports of the country were directed by circular instructions to make quarterly reports of importations and of exportations, with benefit of drawback, of tin and terne plates of the lighter and heavier weights separately, and my reports were made in accordance with the figures so obtained. The blanks called for reports of the production, importation and exportation of the class of plates weighing *heavier* than 63 pounds per 100 square feet, not because it was strictly necessary under the law, but as a check which it was considered would result from the more clear analysis of data thereby secured, and for the more complete information of the Government.

All of these plans had the concurrence of the Board of Managers of the American Tinned Plate Manufacturers' Association, with whom I had previously conferred at Pittsburgh, and who fully recognized the importance of the utmost care in the preparation of the statistics.

The results of the Congressional election of 1891 were regarded by many as a serious misfortune to the new tin plate industry. This was particularly felt to be so by manufacturers, who had plans for enlarging their operations, and who found it desirable to enlist the interests of capital. It was feared that early steps would be taken to repeal the law, and perhaps remove the duty altogether on tin plate and the protection to the industry which it afforded. This was, in fact, done by the House of Representatives at its first session by the passage of what was known as the Mills Bill, which provided for a reduction of the duty on tin plates from 2·2 cents to 1 cent per pound, from October 1, 1892, and made them free of duty on and after October 1, 1894, but the Republican Senate stood as a barrier to that policy.

Despite all opposition, and all causes of discouragement, the American manufacturer, with an abiding faith in himself, with a patience that has seldom been excelled, and with unfaltering courage, stood calmly at his post and worked out the difficult problems that confronted him.

My first report to the department, showing the actual

state of the industry, was dated April 26, 1892. Congress was then in session, and debate was rife between the friends of the law and its opponents. The report showed that during the quarter ended September 30, 1891, the first quarter of the industry's existence, five firms produced, of tin and terne plates, an aggregate of 826,922 pounds. The pioneer manufacturers were Marshall Brothers & Co., and the N. & G. Taylor Company, of your city, the Pittsburgh Electro-Plating Company, of Apollo, Pa., the United States Iron and Tin Plate Manufacturing Company, of Demmler, Pa., and the St. Louis Stamping Company, of St. Louis, Mo. The output for the first quarter was less than 1,000,000 pounds, but it was a beginning.

	Pounds.
The total of tin plates was	152,489
The total of terne plates was	674,433

During the quarter ended December 31, 1891, eleven manufacturing firms produced of

	Pounds.
Tin plates	215,911
Terne plates	1,193,910
Total	1,409,821

During the quarter ended March 31, 1892, nineteen manufacturing firms produced of

	Pounds.
Tin plates	1,099 656
Terne plates	2,109,569
Total	3,209,225

The total product for the nine months ended March 31, 1892, was:

	Pounds.
Tin plates	1,468,056
Terne plates	3,977,912
Total	5,445,968

From these figures you will see that during the three quarters named, the number of manufacturers and the production were practically doubled with each quarter. I may here add that during the fourth quarter of that fiscal year,

ended June 30, 1892, twenty-six firms were manufacturing commercial tin and terne plates, and their output for the quarter was:

	Pounds.
Tin plates	3,071,534
Terne plates	5,129,217
Total	8,200,751

The total production for the first year of the industry was:

	Pounds.
Tin plates	4,539,590
Terne plates	9,107,129
Total	13,646,719

of which about 90 per cent. were of the lighter class named in the law.

The first report showed that during the fiscal years ended June 30, 1888, 1889 and 1890, the average importations of tin plates into the United States had been about 678,000,000 pounds per annum, and the average exportations, with benefit of drawback, were estimated at 150,000,000 pounds per annum. The importations during the fiscal year ended June 30, 1891, were excessive in order to escape the higher duty beginning with July 1st of that year, and amounted to 1,058,000,000 pounds.

It naturally followed that the importations during the fiscal year ended June 30, 1892, would be correspondingly light, and from all the data at hand, it was estimated that the net importations of that year would be 300,000,000 pounds.

The case then stood substantially as follows: that it would be incumbent upon domestic manufacturers, under what was termed the one-third provision, and in order to insure the indefinite continuance of the duty of 2·2 cents per pound, under the law as it then stood, to produce during one of the six fiscal years from July 1, 1891, to June 30, 1897, 100,000,000 pounds of tin and terne plates, weighing lighter than 63 pounds per 100 square feet. Upon no reasonable hypothesis could the one-third net importations, to be

equalled by American producers, exceed 100,000,000 pounds; it was shown that it was likely to fall considerably short of that amount.

The final returns showed this amount to be, in round numbers, 79,000,000 pounds for that fiscal year, and this amount was equalled by manufacturers, under the decision which classed foreign-made black plates as an American product, if coated in this country, during the fiscal year ended June 30, 1893, the third year of the life of the industry.

Not only was it equalled, but there was an excess of more than 14,000,000 pounds of commercial tin and terne plates, no account being taken of American steel, stamped or made into forms, tinned or terne-plated, which was about 9,000,000 pounds. The total excess, therefore, in that year was about 23,000,000 pounds.

While it was now conceded by some of the opponents of the law that tin plates may have been made in a few small "American *dipperies*," as they chose to term them, by the coating of foreign-made plates, it was strongly denied that "black plates" were being made, or could be made, and hence it was argued that the industry was practically a failure. If this had been true, the conclusion would have had much force; but, happily for the credit of American manufacturers, and for the promise of substantial success for the new industry, the facts were all upon the other side. Before proceeding further, it seems desirable to explain here, briefly, what is meant by the term "black plates."

These are plates of sheet iron or steel which are rolled, usually in packs of eight thicknesses. The thickness is generally from 26 to 29 gauge, weights which are commonly used in making the various articles of tinware for domestic purposes. After rolling and separating the sheets in the packs, they are given a special treatment, as a necessary preparation for covering them with a tin or terne coating.

This treatment consists, first, in placing the plates in a moderately strong, heated aqueous solution of sulphuric acid, by which means the scale produced in the process of hot rolling is removed. This first acid solution is known as the "black pickle."

On being taken from the pickle the plates are washed and cleansed in water, and are then ready for the annealing furnace. For this purpose they are placed in iron boxes or "pans," and are closed in with cast or wrought iron covers, the space between the flange of the "pans" and the covers being filled in with sand to exclude the air.

They are now referred to as annealing "pots," and are run into the annealing furnace, where they are subjected to a moderate cherry-red heat for ten or twelve hours, and sometimes more, until they have become thoroughly "soaked," as it is called. After being removed from the furnace, the "pots" must be allowed to cool off before they are opened, otherwise scale would be formed to the injury of the plates.

After cooling, the plates are passed separately through cold rolls, which smooths and, to a certain extent, polishes the surface. This process hardens the plates, and they must again be annealed in order to give them the required toughness and pliability. They are now treated with another acid solution, known in the art as the "white pickle," in order to remove all roughness, and give them a perfectly smooth surface; the surfaces are then cleansed and are placed in boxes of clean water ready for the coating process in the tinning pot or tinning machine.

It is true that the manufacture of a prime quality of black plates requires proper facilities, combined with experience, care and attention; but there is no part of the process of which all the conditions necessary to the most complete success are not clearly understood, and cannot be readily secured. It was believed at that early period of the industry that the manufacture of black plates in this country would be found to be practically commensurate with the demand for the same in the production of commercial tin and terne plates.

As a means of gaining such full information upon the subject as might prove of interest, a circular letter was addressed to manufacturers, and from a large proportion responses were received, a majority of which showed that the work of building and enlargement on substantial lines, as

well as that of actual manufacture, was being successfully and energetically carried forward. These letters were embodied in my first report, and were read with great interest and satisfaction by the friends of the industry, in the debates that were then going on in Congress. I regret that time will not permit my quoting at length from these letters. I can only briefly refer to a few.

Mr. W. C. Cronemeyer, who was at the time, and is now, President of the United States Iron and Tin Plate Manufacturing Company, at Demmler, Pa., already mentioned, and who has been justly recognized as having been influential in urging the necessary measures for the manufacture of tin plates in this country, wrote in part as follows: "This firm started the business of making tin and terne plates in 1874, and continued with but slight interruptions until 1879. They then gave it up altogether, having become convinced that without adequate protection, in harmony with similar rates on the iron industry, the tin plate industry would not prosper." Mr. Cronemeyer submitted many testimonials and original letters, showing the high estimation in which the domestic products were held by American consumers. As illustrating the actual business of the firm about that time he sent me a transcript of two pages, taken from their sales book for April 21 and 22, 1892, showing the sale of 357 boxes to eighteen different firms, in seven different States, extending from Massachusetts to Iowa. Of these, 168 boxes were bright, or tin plates, and all were made from American-rolled sheets.

The St. Louis Stamping Company, as before shown, was one of the first to engage in the new industry. From their letter it appeared that they were then running four sets of hot rolls and four sets of cold rolls in the manufacture of black plates. They had ten tinning stacks in operation, and six building. Further improvements and additions were being made in their rolling mill.

The firm of Marshall Bros. & Co., of this city, had been recently reconstructing their rolling mills for the manufacture of black plates, and had erected a tinning plant complete, all of which, as shown by their letter, were in successful operation.

The Blairsville Rolling Mill and Tin Plate Company, of Blairsville, Pa., were nearly ready to commence operations. Their letter gave a concise description of their plant, which was built in a very substantial manner, complete in all respects for the manufacture of black plates, as well as of tin and terne plates.

The letter of the New Castle Steel and Tin Plate Company, of New Castle, Pa., now one of the largest and most successful tin plate manufactories in this country, or in the world, showed that they received their charter February 29, 1892, and had already let their contracts for the erection of a complete plant, including a rolling mill to roll their sheets for tinning from Bessemer steel billets.

Their buildings were to be made entirely of iron, and their contracts called for the very best machinery that could be made in the way of mills and tinning machines, to turn out a weekly production of 2,500 boxes of roofing and bright plates. What they further said reflected the general sentiment of manufacturers as expressed in their letters.

They stated: "We are investing our money in a plant with the expectation of being able to pay our workmen American prices. This can be done under the present tariff. The agitation in Congress for reducing the present duty on tin plates has done more to retard the development of the industry than all other causes."

The N. & G. Taylor Company, of this city, wrote that they were doing all in their power to hurry the completion of their works, which they expected to be in operation by July 1st. They were to put in twenty-four tinning stacks, and have to-day one of the largest and best-equipped coating factories in the country. While they do not roll their own black plates, they use largely those of American manufacture.

The Record Manufacturing Company, of Conneaut, O., although not large manufacturers, explained in detail and in an interesting manner the difficulties which they had encountered in being limited to the foreign supply, and the advantages they had already experienced in their new manufactures, they themselves being large consumers of

plates. The firm also gave testimony to the superior quality of American black plates, although their original expectation appears to have been to use only foreign-made plates.

The company said that, judging from their past month's experience, they would regret exceedingly to go back to foreign plates for supplies for their factory, for quite a number of reasons, one being that a superior quality of metal is used in this country for the manufacture of black plates.

They stated that during the last month they had used from their own plant upwards of 680 boxes, and had not had a single sheet crack under their dies, which was something they could never say of the highest grade of foreign plates.

They had, besides, sold from 200 to 300 boxes in sample lots, one, two and three boxes in a place, and had had the highest commendation from those who had received them, both as to quality of metal and coating.

During the last month, they stated they had received from American mills about 200,000 pounds of black plates, and in the following month they expected to utilize more than double that quantity.

The letter added that, at the time the McKinley Bill was passed, they thought that it was a great leap in the dark, and that they wrote their representatives in Congress, Representative Taylor and Senator Sherman, upon the subject. They at that time believed, however, that if Congress would let the law remain as it was, in a short time the country would see as cheap and cheaper tin plates than it ever saw before.

A number of weighty reasons other than those mentioned were presented by this firm why they would regret to go back to the use of foreign-made plates, reasons which were of general application, and hence of general interest to all tin plate consumers.

The Norton Brothers, of Chicago, manufacturers of tin cans on an immense scale, wrote that they had already expended more than $100,000 in an effort to perfect a process for the direct rolling of fluid steel into sheets from the open hearth furnace, without first casting an ingot, as was the common practice, and at the time they had strong hopes

of success, hopes which have not, I believe, been as yet realized.

They further stated that during the year then past, they had perfected an entirely new system of tinning the black sheets by what is known as the palm-oil process, which would greatly improve the quality of the tin plates over those which were then furnished by the Welsh makers of the cheaper grades for canning purposes. This, they stated, was the quality of tin plates which was their specialty, and which they used in their business more extensively than any other house in the United States.

They explained that nearly all the plates of this character made in Wales at that time were being tinned by the use of what is termed "flux," that is, a solution of diluted muriatic acid. The cleaned and pickled plates are immersed in this solution before being dipped into the tinning pots. The reason for the general adoption of this process in Wales is that tin plates thus made are more rapidly tinned than where the old hand-made, palm-oil process is used, in which the sheets are thrown into vats of heated palm-oil, and allowed to soak, thus evaporating the water in the plates, as a preparatory step to tinning.

The firm stated that they had had great difficulty in the last few years in the use of these acid-coated plates, as the acid in time causes the steel to rust out underneath the tin coating, and pin-holes appear in the plates sometimes after the goods are made up, thereby causing great loss to the user.

"We determined," the letter continues, "to overcome this difficulty before engaging extensively in the manufacture, and are happy to state that we have devised a process by which this is accomplished, and whereby we are able to produce a perfectly coated tin plate by as rapid working machinery as is used in the acid process, and entirely with the use of a palm-oil or grease flux, instead of the objectionable acid flux."

The firm stated that they were using from 25,000,000 to 30,000,000 pounds of tin plates yearly in their business, and they are now coating that amount by their own process as

before described in their large coating factories at Maywood, near Chicago, and at Baltimore, Md., using solely American-rolled black plates.

This must conclude our hasty glance at these letters. Less than five years have since transpired, but their perusal throws a strong light on the situation at that time, and enhances our respect and sympathy for the early pioneers in American tin plate manufactures.

A brief survey of the then existing conditions may not prove uninteresting, and I can perhaps do no better than to give the conclusions of my report, which I will present as if read of the date they were written. In presenting my conclusions I said:

From my investigations it would appear:

(1) That tin and terne plates are being made in this country by American manufacturers in commercial quantities, and are being offered and purchased in quantities by American consumers throughout a large part of the United States.

(2) These domestic plates have been extensively tested by American consumers, and have given universal satisfaction, the testimony going to show that they are equal, if not superior, to foreign-made plates of similar kinds. The features of excellence comprise toughness and pliability of the black plates or metal sheets, and also perfection of coating.

(3) The development of the new industry has largely stimulated the manufacture of American black plates. It has been shown that the number of companies or firms whose names are found in the appended list, and who are making or are preparing to make black plates, is seventeen. Besides these, at least five other firms, whose names have been given, are known to be engaged in the manufacture. I am advised that manufacturers of black plates are now keeping tin plate manufacturers regularly informed of their increased facilities for filling orders.

(4) Manufacturers of machinery have already turned their attention to the special forms of machinery required in the production of tin and terne plates. This is the case with such firms at Pittsburgh, Pa., at Youngstown, Ohio, and at other points.

(5) The industry has developed with satisfactory and, in view of attendant difficulties, with surprising rapidity, and has passed the experimental stage. Capital, at first cautious, is now being freely invested in this branch of manufactures.

(6) A comparison of the relative increase in production of tin and terne plates for the past three quarters serves to illustrate the correctness of the conclusions above reached.

The chief ultimate object to be attained was the manufacture of tin plates, the reason being that the consumption of tin plates in this country hitherto has been greatly in excess of that of terne plates. The importation of the former, as shown by the returns for the first six months of the present fiscal year, was about 93 per cent. of the entire importations.

By comparison made below it will be seen that the ratio of increase in the production of terne plates during the last quarter was greatly diminished, while that of tin plates was largely augmented. While the methods of manufacture are the same, terne plates are less difficult to make than tin plates, and as a consequence, manufacturers generally began their experimental operations with the former.

During the first quarter of the fiscal year, the production of terne plates, as compared with that of tin plates, was in the ratio of 4 to 1. During the next quarter, with more than double the number of manufacturers in the field, the ratio was more than 5 to 1. During the third quarter, ending March 31, 1892, with the number of manufacturers again practically doubled over that of the previous quarter, it was largely reduced, the ratio for that quarter being considerably less than 2 to 1.

During the same quarter the increased production of terne plates over that of the previous quarter was less than 60 per cent., while the increased production of tin plates over that of the previous quarter was in excess of 500 per cent.

These figures go to show that even now the relative production of tin plates and terne plates in this country does not depend upon the ability of manufacturers to produce the former, but, as is the case with most manufactures,

upon the law of demand and supply. The same remark applies with respect to the relative quantities of plates made of the lighter and heavier weights described in the law. An inspection of the exhibits will show that of the entire production during the first quarter of the fiscal year, only about 70 per cent. consisted of the class of plates weighing lighter than 63 pounds per 100 square feet. During the second quarter the production of the lighter class, as compared with the whole, was about 87 per cent., and during the third quarter, ended March 31, 1892, it was about 91 per cent. Should this increase continue in the same ratio until the beginning of the next fiscal year, the percentages of the lighter class of plates imported and produced in this country would practically correspond.

(7) The present quarter will, in all probability, witness the production of as much tin and terne plate in this country as did the previous three quarters taken together. This means 10,000,000 pounds of tin and terne plates of American production during the year, to take the place of foreign-made plates. In the lowest estimate hereinbefore made of 680,000,000 pounds of imported tin and terne plates to supply the wants of the country during the present fiscal year, no account was taken of the home production for the year. In point of fact, however, the presence and consumption of 10,000,000 pounds of domestic plates would tend to confirm that estimate.

(8) The future development of the canning industries of the country, and the embarrassments that the industries have struggled against on account of their dependence upon a foreign country for their supply of tin plate, afford a strong reason for the establishment of tin plate manufactures in this country. This achievement means, on the basis of recent yearly importations, the expenditure in the United States, instead of foreign countries, of over $20,000,-000 in gold, or its equivalent.

(9) The certainty of increased production, together with the improvements that have already been made and that are in progress, to cheapen the cost of manufacture, and at the same time better the quality of the plates, are most encouraging with respect to reduced prices.

(10) The letters from manufacturers, which are herewith submitted, show that they are meeting with encouraging success and that they deprecate any change in the present law.

We have seen that during the fiscal year ended June 30, 1892, the first year of the industry, the production of commercial tin and terne plates was 13,646,719 pounds. Of this amount, over 9,000,000 pounds, or more than 68 per cent., were made from American black plates. Twenty-six firms were engaged in the work of actual production during the quarter ended June 30, 1892.

Passing rapidly over the work of the four following years, the reports show that during the quarter ended June 30, 1893, thirty-five firms were engaged in actual production, and during that year about 100,000,000 pounds of commercial tin and terne plates were manufactured. During the quarter ended June 30, 1894, forty firms were producing, and during that year the production was more than 139,000,000 pounds.

On the 28th of August, 1894, the enactment known as the Wilson Bill became law. The duty on tin and terne plates was reduced thereby from 2·2 to 1·2 cents per pound. The duty on black plate, which, under the McKinley law, had been 1·65 cents per pound, and which many had regarded as too low, was placed by the Wilson Bill at 1·225 cents per pound. The purpose of this was to leave the duty on black plates in harmony with that on other products in the iron industry. The duty was reduced on steel billets, which may be regarded as the raw material from which black plates are rolled, and from this and other causes the market price of billets became unprecedentedly low. The duty of 4 cents per pound, which had been placed upon block tin by the McKinley law to encourage the development of tin mining in this country, was removed, and block or pig tin, which forms the coating of tin plates, was admitted free of duty.

This worked no hardship to those interested in tin mining, for during the three previous years it had been demonstrated that, under existing conditions, tin mines could not

be profitably worked in the United States. Considerable outlays had been made on the Temescal mine in California, and the Harney Peak mines in North Dakota, with results, at times, more or less promising, but the work on both had been abandoned before the passage of the Wilson Bill.

As before indicated, it had become apparent that the United States must look for its tin to the East Indies and other sources of supply, as has been for years past, to a greater or less extent, the case with Welsh manufacturers.

Besides the conditions mentioned, American manufacturers felt that they could now rely upon the duty remaining permanently as fixed by the Wilson Bill. They had mastered the difficulties of manufacture, and were no longer, as they had been at first, almost entirely dependent upon foreign labor. Domestic tin plates had now secured a high standing with American consumers, and, other things being equal, their patriotic impulses led to a demand for the home product.

The general business conditions, growing out of depressed wages and low prices for all kinds of raw material, were favorable to the erection of new plants at a minimum of cost. From all of these causes the growth of the industry during the fiscal year ended June 30, 1895, the fourth year of its existence, was well-nigh marvellous.

The special provisions of the McKinley law, which I have explained, and which made the statistics a necessity, had been abrogated, but the public interest remained so great in the subject, that the department directed a continuance of the work with yearly reports.

My report for the fiscal year ended June 30, 1895, showed that the production in the United States of commercial tin and terne plates was about 194,000,000 pounds, as against 139,000,000 during the previous fiscal year. Forty-eight firms were producing during the quarter ended June 30, 1895, as against forty during the corresponding quarter of the previous fiscal year.

During this fiscal year, seven firms (coating factories) permanently discontinued production, and their names were accordingly dropped from the list of manufacturers given

with my report. Twenty-seven new firms engaged in the active business of building, or of building and production during the year, of which seventeen were making or preparing to make black plates. Twenty-eight rolling mills were producing black plates during the quarter ended June 30, 1895, against twenty that were producing during the quarter ended June 30, 1894.

My last report (that for the fiscal year ended June 30, 1896), which was the fifth year of the industry, showed that the production of commercial tin and terne plates in the United States during that year amounted to more than 307,000,000 pounds, against about 194,000,000 pounds during the previous fiscal year, an increase of more than 58 per cent. Of the entire production, about 265,000,000 pounds, or more than 86 per cent., belonged to the class of plates weighing lighter than 63 pounds per 100 square feet, and of this lighter class, 182,000,000 pounds consisted of tin plates.

The quantity of American sheet iron and steel made by stamping and other manufacturing firms into articles and wares, which were afterwards tinned or terne-plated, was 10,586,110 pounds, showing a consumption of American sheet iron and steel in this class of manufactures of more than 4,000,000 pounds in excess of that for the year immediately preceding, and of nearly 4,000,000 pounds in excess of the average for the four previous years.

The production of black plates in the United States during the year was 334,000,000 pounds, that for the previous year having been 185,000,000, showing an increased production of 149,000,000 pounds, or about 80 per cent. more than that of the previous year.

Thirty-six rolling mills were producing black plates during the fiscal year ended June 30, 1896, an increase of seven over the previous fiscal year.

The proportion of American rolled sheets used during the year, compared with the entire production of commercial tin and terne plates, was 98½ per cent., against about 83 per cent. used during the previous fiscal year.

During the year six firms (coating factories) permanently discontinued production, and three new firms engaged in

the active business of building, of which two were preparing to make black plates.

The total number of firms engaged in tin and terne plate manufactures June 30, 1896, was 74, of which there were making or preparing to make black plates, 43. The number of firms making black plates only was 7. The total number of hot mills (for rolling black plates) completed June 30, 1896, was 180; the number building was 8; completed and in process of construction, 188.

The number of tinning machines and sets completed June 30, 1896, was 430; the number building was 30; completed and in process of construction, 460.

Sixteen stamping or other manufacturing companies used American sheet iron or steel in the production of articles and wares tinned or terne-plated.

In 1893 the department rendered a decision to the effect that only tin and terne plates made from black plates rolled in the United States could be considered as American tin plates within the meaning of the law. It will be of interest to find whether, under this ruling of the department, American manufacturers have yet complied with what may be termed the one-third requirement, which, by implication, would have continued the duty of 2·2 cents per pound, had the law remained unchanged. We take the figures as we find them for the fiscal year ended June 30, 1896:

	Pounds.
The importations of tin and terne plates in that year, of the class weighing lighter than 63 pounds per 100 square feet, were, in round numbers	371,000,000
The exportations of the same class of plates with benefit of drawback, during the same period, were . . .	135,000,000
Making thereby the net importations	236,000,000
One-third of which is, say	79,000,000
The aggregate of commercial tin and terne plates of the lighter class, produced in the United States during the same period wholly from American rolled sheets was, in round numbers	265,000,000

or more than $3\frac{1}{3}$ times the quantity that would have been necessary to meet the one-third requirement under the McKinley law, had it remained in force.

The production, from American-rolled sheets, of tin plates alone, of the class weighing lighter than 63 pounds per 100 square feet, during the fiscal year ended June 30, 1896, was about 182,000,000 pounds, or more than 2¼ times the quantity necessary to have met the one-third requirement of the McKinley law.

If these statistics are obtained for the present fiscal year, which is the last of the six fiscal years named in the McKinley law (and it is not improbable that they will be), they promise to exhibit even more striking results than those which we have just been considering.

[The lecture was fully illustrated, at its close, with the aid of a series of lantern slides. Among other interesting views thus shown was the accompanying condensed statistical exhibit of the development of the tin plate industry, since the passage of the McKinley Tariff Act of October 1, 1890.]

SUMMARY STATEMENT OF PRODUCTION OF TIN AND TERNE PLATES IN THE UNITED STATES FOR THE FISCAL YEARS 1892, 1893, 1894, 1895 AND 1896, RESPECTIVELY.

Period from—		Tin Plates.			Terne Plates.			Tin and Terne Plates.	Amount Made From—		Total.
		Lighter than 63 Pounds per 100 Square Feet.	63 Pounds per 100 Square Feet and Heavier.	Total.	Lighter than 63 Pounds per 100 Square Feet.	63 Pounds per 100 Square Feet and Heavier.	Total.	Aggregate Production.	American Black Plates.	Foreign Black Plates.	
		Lbs. Net.	*Lbs. Net.*	*Lbs. Net.*	*Lbs Net.*	*Lbs. Net.*	*Lbs. Net*	*Lbs. Net.*	*Lbs. Net.*	*Lbs. Net.*	*Lbs. Net.*
July 1, 1891, to Sept. 30, 1891,	First fiscal year under law of Oct. 1, 1890.	134,869	17,620	152,489	442,552	231,881	674,433	826,922	785,547	41,375	826,922
Oct. 1, 1891, to Dec. 31, 1891,		181,501	34,410	215,911	1,046,879	147,031	1,193,910	1,409,821	1,200,661	209,160	1,409 821
Jan. 1, 1892, to Mar. 31, 1892,		1,018,698	80,958	1.099 656	1,907,869	201,700	2,109,569	3,209,225	2,132,082	1,077,143	3,209 225
Apr. 1, 1892, to June 30, 1892,		2,796,941	274.593	3,071,534	4,795,236	333,981	5,129,217	8,200,751	5,178,263	3,022,488	8,200,751
Total		4,132,009	407,581	4,539 590	8,192,536	914,593	9,107,129	13,646 719	9,296,553	4,350,166	13,646,719
July 1, 1892, to Sept. 30, 1892,	Second fiscal year under law of Oct. 1, 1890.	3,337,036	274,331	3,611,367	6 875,958	465,400	7,341,358	10,952,725	5,920,082	5,032,643	10,952,725
Oct. 1, 1892, to Dec. 31, 1892,		5,274,434	864,305	6,138,739	12,684,646	933,106	13,617,752	19,756,491	8,043,449	11,713,042	19,756,491
Jan. 1, 1893, to Mar. 31, 1893,		14 333,875	9 0,699	15,244,574	13,803,461	518,364	14,321,825	29,566,399	11,371,968	18,194,431	29,566,399
Apr. 1, 1893, to June 30, 1893,		19 425 336	1,323,091	20,748,427	18,115,741	679,419	18,795,160	39,54[illegible],587	18,264,225	21,279 362	39,543,587
Total		42,370,681	3,372,426	45,743,107	51,479,806	2,596,289	54,076,095	99,819,202	43,599,724	56,219,478	99,819,202
July 1, 1893, to Sept. 30, 1893,	Third fiscal year under law of Oct. 1, 1890.	13,158,982	702,181	13,861,163	12,807,230	477,087	13,284,317	27,145,480	8,794,027	18,351,453	27,145,480
Oct. 1, 1893, to Dec. 31, 1893,		14,048,471	633,574	14 682,045	12,2[illegible]2,823	416,373	12,669,196	27,351,241	15,907,669	11,443,572	27,351,241
Jan. 1, 1894, to Mar. 31, 1894,		24,815 641	1,497,920	26,313,561	11,486,747	460,103	11,946,850	38,260,411	27,765,162	10,495,249	38,260,411
Apr. 1, 1894, to June 30, 1894,		25,397,731	1,355,265	26,752,996	19,046,617	666,722	19,713 339	46,466,335	33,501,344	12,964,991	46,466,335
Total		77 420,825	4,188,940	81,609,765	55,593 4[illegible]7	2,020,285	57,613,702	139,223,467	85,968,202	53,255,265	139,223,467
July 1, 1894, to Sept. 30, 1894,	First fiscal year under law of Aug. 28, 1894.	27,267,025	2,918,659	30,185,684	15,932,495	2,227 454	18,159,949	48,345,633	33,506,17[illegible]	14,839,458	48,345,633
Oct. 1, 1894, to Dec. 31, 1894,		15,065,370	3,905,796	18,971,166	12,647,045	1,6[illegible]2,819	14,299,864	33,271,030	24,891,802	8,376,228	33,271,030
Jan. 1, 1895, to Mar. 31, 1895,		22,938,252	5 361,202	28,299,454	13,683,645	2,628,042	16,311,687	44,611,141	39,156,348	5,454,793	44,611,141
Apr. 1, 1895, to June 30, 1895,		37,985,496	4,886,149	42,871,645	20,671,031	4,030 503	24,701,624	67,573,269	63,019,609	4,553,660	67,573,269
Total		103,256,143	17,071,806	120,327,949	62 934,216	10,538,908	73,473,124	193,801,073	160,576,934	33,224,139	193,801,073
July 1, 1895, to Sept. 30, 1895,	Second fiscal year under law of Aug. 28, 1894.	41 861,816	4 239,198	46,101,044	21,930,412	2,892,873	24,823 285	70,924,329	68,887,553	2,036,776	70,924,329
Oct. 1, 1895, to Dec. 31, 1895,		40 006,81	8,648,953	48,655,764	19,687,699	3,159,193	22,846,892	71,502,656	70,253,017	1,249,639	71,502,656
Jan. 1, 1896 to Mar. 31, 1896,		46,604,697	7,302,709	53,907 406	16,08[illegible],087	2,725,884	18,807,971	72,715,377	72,519 7[illegible]1	195,596	72,715,377
Apr. 1, 1896, to June 30, 1896,		53,572,215	10,352,752	63,924,967	25,174,125	2 987,167	28,161,292	92,086,259	91,341,747	744,512	92,086,259
Total		182,045,569	30,543,612	212,589,181	82,874,323	11,765,117	94,639,4[illegible]0	3[illegible]7,228,621	303,002,098	4,226,523	307,228,621

AN ALL-WROUGHT STEEL PULLEY.

BY EDWARD G. BUDD,
Member of the Institute.

The different branches of the industrial world are so dependent on one another that progress in one line is invariably accompanied by, and keeps step with, progress in all the others. When an advance has been made in one branch, it will be found that the improvement is called for by some new demand in some branch which it serves, and has been made possible by an advance in another which has preceded it. Many lines of industry have found progress limited by the strength of the material used.

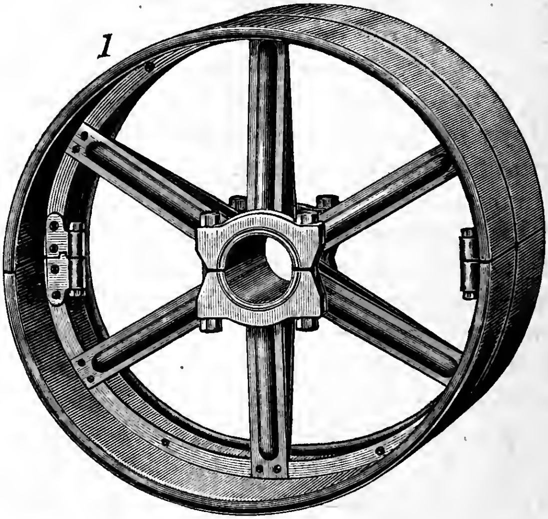
As the manufacturers of material improve their product, all the industries using that material are aided. This has been noticeable in gun and armor manufacture.

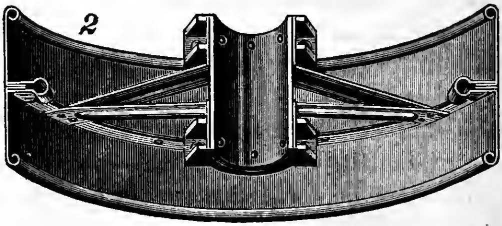
The recent advances in the manufacture of mild steel by the Bessemer and open-hearth processes have enabled those who use that material greatly to improve their product and to cheapen its cost. The benefit to the arts arising from this cause is most noticeable in the cases in which the steel-worker has been enabled to produce, on the practical commercial scale, articles formerly made of brittle cast iron. This has been realized in the case of many familiar articles of hardware and household use.

At present a mild grade of steel, of homogeneous structure, carefully rolled to thickness and in long sheets of convenient widths, can be bought at prices, pound for pound, below the cost of castings. In the hands of the skilled steel-worker this sheet can be formed into many articles of complicated structure without taking from its original strength. Sprocket-chains and other parts of the bicycle, locks, hinges, shelf brackets, and many more simple articles are made cheaply of this strong, ductile material.

It is the purpose of the writer to describe in this communication, an ordinary belt-wheel made entirely of such steel, and representing the highest development of the sheet metal worker's art up to the present day.

Figs. 1 and *2* will give a general idea of the design. The rim is built of four segments. It is divided once transversely and once longitudinally. A means of attachment to the arms is given by the deep flanges which are turned in at the center of the face. The rim edges are stiffened by being turned into a curl, which gives an attractive appearance and avoids scaring the belt in throwing on or off.





The hub is composed of two half cylinders of heavy metal. The hub and rim are connected by four spider pieces—two in each half pulley. As will be seen in *Fig. 2*, there is a spider piece starting at each end of the hub, and which embraces and is fastened to the hub-shell. As the spider arms branch toward the rim, the two opposite arms approach each other, forming a pyramid, and at the

ends they are riveted to the deep flange in the center of the rim.

The arms being of a flat piece, with its edges lying in the direction of rotation, and the two opposite arms being dished towards each other, makes the structure well suited to resist the strains to which it is to be subjected. The lateral stiffness is greatly increased by the deep corrugations which run the length of the arms.

Figs. 3, 4 and *5* will show clearly the method of making one of the spider sections. A flat piece like *Fig. 3*, called

Fig. 3

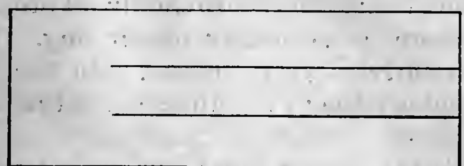


Fig. 4

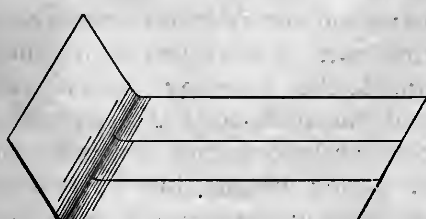
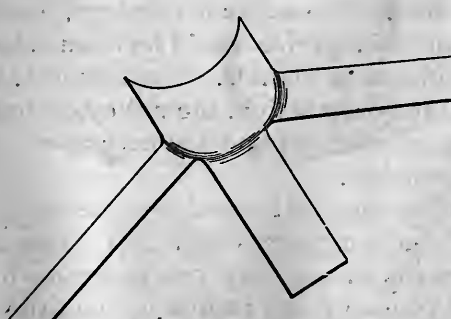


Fig. 5



the hand, is slit as there shown, giving three fingers and a palm. The palm and fingers are then bent at right angles, as in *Fig. 4*.

In another operation the palm is given a convex shape and the fingers take the shape of radial arms, *Fig. 5*.

The ends of the hub are embraced by hub clamps which are attached to each half pulley. The pulley is clamped to the shaft by means of four bolts.

The company building this pulley has taken a step in line with others in advanced practice, by advocating their use in the heaviest service without keys.

The steel hub shell on a steel shaft has a very high coefficient of friction. The clamps are designed so that they make the shell hug the shaft closely all around, and with four bolts there is no danger of slipping. Pulleys thus clamped have driven power-presses, with the severe shock and jar to which they are subjected, without any sign of slipping.

No machine shop operations are needed on this pulley. By carefully designed dies and shears each part is made to exact size. The rim and arms are pressed to their final shapes by heavy and specially designed hydraulic machines.

One of the features of interest in the manufacture of this apparatus is the economy of material. The actual gross weight of the stock, bolts and rivets used in a pulley of 24 inches diameter by 6 inches face is 26 pounds 5 ounces. The finished pulley weighs just 24 pounds. The total waste in punchings and shearings is, therefore, only 2 pounds 5 ounces, and this scrap is salable at a rate which materially reduces the loss. The waste in turnings, borings and gates on a cast pulley of this size would be about 15 pounds with a finished weight of 75 pounds. Furthermore, being entirely symmetrical in construction, the pulley, as made, is in perfect running balance without the necessity of adding counter-balance weights.

In designing the ideal wheel to be used under the ideal conditions, the engineer would find three strains to be resisted. In the case of a 24-inch pulley with a 6-inch face, there would probably be in running conditions 450 pounds on the tight side and 150 pounds on the slack side of the belt. This would give a force of 600 pounds, tending to crush the rim and compress the arms. The rim overhang-

ing on each side of the arms, the action of the belt would be to cause buckling of the edges. Then the difference between the tension on the tight and slack sides of the belt, which is equal to 300 pounds, is the effective work of the belt and gives a bending strain to the arms. These calculated strains are all trifling, but frequently, by accident or by quick variations in speed of driving or driven pulley, there are strains ten times as great as those exerted by the belt.

In designing a structure subject to so great variations of stress, the engineer would choose a material which combines strength and toughness, rather than the brittle cast iron.

The weakness of cast iron, when used as the material of pulleys, has been accentuated by casting the rim, arms and hub in one piece. The uniting in one casting of heavy and light sections, and of such as lie at right angles to one another, is as great a mistake, in the moulder's art as were the Siamese twins in the living world.

Instead of pulling together, these three parts pull against one another, and often resist even to open rupture.

The foundryman guards against this happening in his hands by making the casting much too heavy.

The cast-iron pulley to-day has reached its full development. It is true and graceful, is given tolerable balance by adding weights to the light side, and is made to fit exactly one standard size of shaft; but in spite of all these good qualities, worked out by the best engineering skill, it is defective because of the prime mistake in the first operation of making them. The wood pulley, being light, interchangeable as to bore, and cheap, has been sold largely of late years. It is not durable, however, and increases the fire risk where it is carried in stock by dealers. It has been left to Yankee genius and Philadelphia capital to produce a pulley which, being made of the very best and strongest material, corrects the mistake in the standard wheel.

Gears, cranks and levers are each used on many machines, but pulleys are used more than any other mechanical device. There is no factory that does not use them in

quantities. In the present state of the mechanical world they are as universal as machinery itself. Now, a mechanical method which, on a device in such general use, at once reduces the amount of material used to one-third the former practice, reducing also to the same extent the weight and corresponding inertia and frictional resistance to shafting rotation, should be worthy of the attention of the mechanical world. This is accomplished without any expensive operations, and by methods essentially American in their origin, and by which Americans have made not only such simple articles as hardware fixtures, but also such refined ones as watches.

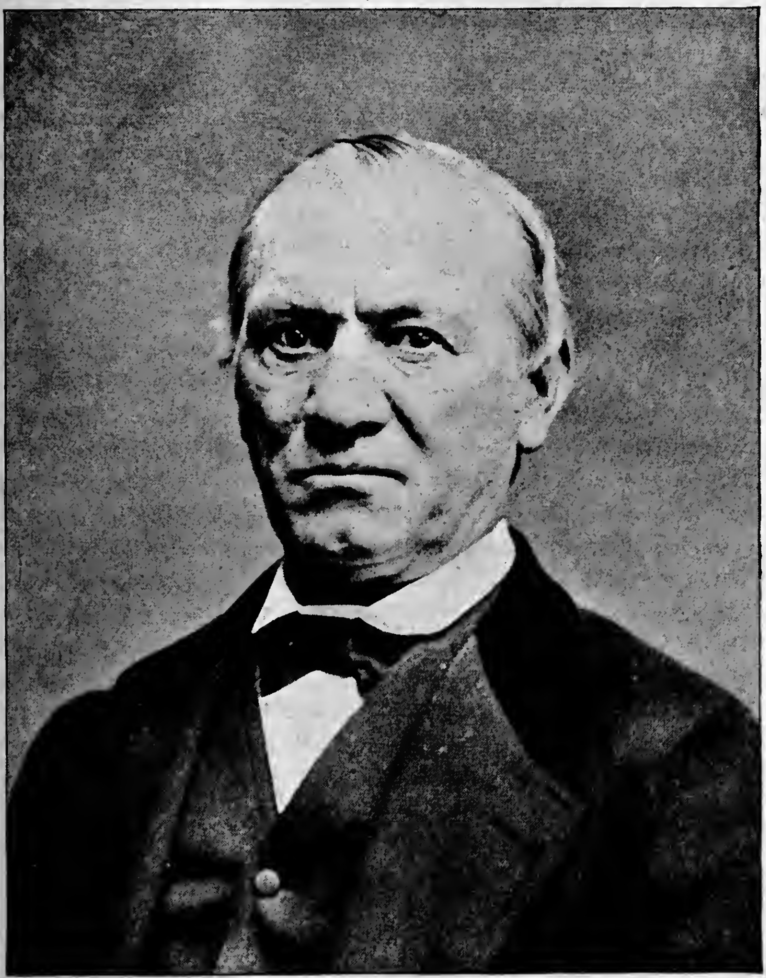
The pulley here described is the invention of Mr. Thomas Corscaden, who has long been engaged in making specialties in steel, some of which are familiar articles to the public to-day. He conceived the idea of making this pulley as far back as 1888. Dull times giving leisure and stimulus to take up something new, drawings and models were made and experimented with. In 1892 patents were taken out on the pulley and on the machinery for making it. With the co-operation of Mr. George V. Cresson, a member of this Institute, and an extensive manufacturer of power-transmitting machinery, the American Pulley Company was formed, and a factory was equipped in Philadelphia for the purpose of manufacturing the pulley under Mr. Corscaden's patents. Under his superintendence special machinery, dies and tools were designed and built, which permit of the production of several hundred pulleys daily.

The pulley has attracted the attention of the engineering public, both at home and abroad, and its extensive adoption already appears to be well assured.

IN MEMORIAM.

ROBERT WRIGHT.

Robert Wright, son of Jonathan and Mary Wright, was born February 19, 1817, at Keighley, Yorkshire, England, and died January 11, 1897, after having lived a life of great usefulness, characterized by a modesty as conspicuous as



ROBERT WRIGHT. (1817–1897.)

were the great events in which he had been one of the chief actors.

His parents emigrated to Philadelphia in 1820, and at an early age he was apprenticed as a mechanic to a firm of Englishmen, named Hyde & Flint, whose place of business was on Beach Street. He subsequently entered the employ of Garrett & Eastwick, who at that time were located in Wagner's Alley, near Seventh and Race Streets. The training he here received and his natural gifts, coupled with the fact that the development of the railway systems of America was in process of evolution, gave him the opportunity, as a mechanic, to prove his worth. His employers, Garrett & Eastwick, were in the front rank as constructors of railway equipment, and it was not strange, therefore, that when Messrs. Harrison, Eastwick & Winans obtained the contract from the Russian Government for the construction and equipment of the line of railway from St. Petersburg to Moscow, they turned to Robert Wright as the mechanic best suited to assume charge of their enterprise.

Accordingly, in 1844 he went to Russia, under a contract with his new employers, and at a salary which, even in these days, would be considered an extremely satisfactory compensation, and which in the days of fifty odd years ago, must have seemed princely to the then young mechanic.

In all the manifold departments of construction and equipment he was prominent, and, enduring the hardships incident to the Russian climate, he kept persistently at his work until the latter part of 1850, when he returned for a short visit to Philadelphia. Returning to Russia in 1851, under a new contract and at an increased compensation, he assumed charge of the Alexandroffsky Head Mechanical Works, near St. Petersburg, and, during the Crimean War, constructed the marine engines for the Russian gun-boat fleet. His achievements in the field of marine engine construction were crowned with as much success as he had already acquired in that of railway equipment.

For his eminent services at this time, the Order of St. Stanislaus was duly conferred upon him by the Czar; and the official notification of the conferment of this honor was

conveyed to him in a letter, a translation of which is herewith given:

"To ROBERT WRIGHT, Chief Mechanic at the Alexandroffsky Head Mechanical Works, near St. Petersburg, Russia:—In consequence of the intermediation of the Ministry of Marine, His Imperial Majesty, by the decision of a Committee of Ministers, has deigned most graciously to grant you, for your exertions in the construction of screw engines for the gun-boat fleet, a silver medal to be worn on the neck, on a ribbon of the Order of St. Stanislaus. The Chancery of the Ministry of Marine informing you of His Majesty's desire, forward the medal herewith.

January 3, 1857. (Signed) COUNT TOLSTOY."

Prior to this mark of imperial distinction, he had become prominent by rescuing a large vessel (for a ship-building company in Perm, Russia), which, owing to some imperfection of construction, had sunk, and having raised the vessel and rebuilt her engines and boilers, he was duly honored by the presentation of a gold cup, suitably inscribed, as a mark of the esteem which his great mechanical skill and ingenuity had gained for him.

Returning to Philadelphia in 1856, and having acquired a competency as a result of his labors, he retired from active mechanical work.

He married, in 1840, Emily Shoch, daughter of George P. and Maria Shoch, and had two children, a daughter, who died in Russia, and a son, who fell a victim in the Civil War, at Murfreesboro, Tenn.

Although taking a lively interest in all the questions of the day, a defect in his hearing, which ultimately approached total deafness, precluded the possibility of his engaging in active work.

He was a great believer in the ability of canals to compete advantageously with our railway systems, and deplored the policy which has resulted in the acquisition by the railroads, through lease or purchase, of the principal canals of the United States, and in the diversion of traffic therefrom, and the falling into decay of those magnificent monuments to the engineering talent and ability of seventy years ago.

He was an earnest vegetarian, a God-fearing and deeply

religious man, who had pronounced convictions of his own, but who was ever tolerant of the opinions of others; and thus for forty years this modest, worthy man lived quietly in our midst, his life saddened by the loss of his children, but brightened by schemes he was contemplating for the ultimate good of his fellow-men.

He had been greatly aided, as a struggling young mechanic, by two of our philanthropic institutions, the FRANKLIN INSTITUTE and the Apprentices' Library. He was a friend of dumb animals, and an admirer of the good work done by the Pennsylvania Society for the Prevention of Cruelty to Animals; and it is to these three worthy institutions that his estate will eventually come, absolutely unhampered by any conditions.

And now, since his modesty was such that he gave no thought to the perpetuation of his name in connection with his munificent gifts, it is right and fitting that we should here place on record the sterling virtues and worth of this honest mechanic, who so lived and died that hundreds, nay, thousands, all unconscious of the donor, may derive great benefits as the result of his industry and thrift.

FREDERICK FRALEY HALLOWELL.

AN EFFICIENCY SURFACE FOR PELTON MOTOR.*

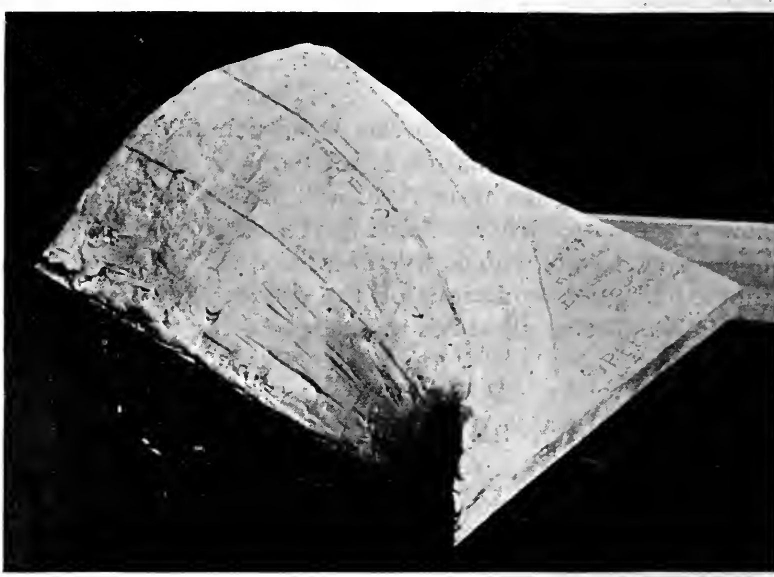
By W. KENDRICK HATT,
Associate Professor Applied Mechanics, Purdue University, Lafayette, Ind.

When a jet impinges against a series of moving cup-shaped vanes, as in the Pelton motor, the entire kinetic energy of the jet may, theoretically, be given up to the motor, provided the angle of total deviation (relatively to the vane) of the jet leaving the vane be 180° from its original direction, and provided the vanes move with a velocity equal to half the velocity of the particles of the jet. For any other velocity of the vane (the speed of the jet remaining constant), the efficiency of the motor is reduced;

* Paper presented to Indiana Academy of Sciences, December 27, 1896.

so that the efficiency of the motor for a given head of water will vary from zero value at zero vane speed to its maximum value of unity for a vane speed equal to one-half the speed of the jet, and will reduce to zero again for a speed equal to the speed of the jet. In any actual Pelton wheel, the friction in cups, lateral escape of water, interference of cups with each other's supply, etc., combine to reduce the efficiency.

Now, if the three variables—speed of cup, head of water, and efficiency—be represented respectively on the three axes,



X, Y, Z, an efficiency surface will result. Such a surface will have its zero efficiency contours, one coincident with the Y axis and the other a parabola tangent to the X axis at the origin. There will be a ridge of unit efficiency extending from a point of height equal to unity at the zero of co-ordinates, in the curve of a parabola, whose projection on the $X\ Y$ plane lies midway between the two zero contours. The section parallel to the $Z\ X$ plane will be a parabola convex upwards. The equation of the surface may be obtained thus: The power exerted on a series of vanes, moving with

velocity $= v$, by a jet whose particles move with a velocity $= c$, is (Church's Mechanics):

$$(1) \qquad L = \frac{Q\,m}{g}[1 - \cos a](c - v)\,v$$

where Q is the quantity of water used, and the g the acceleration of gravity, and m is the heaviness of the water. For Pelton motor $\cos a = -1$; therefore,

$$(2) \qquad L = \frac{Q\,m}{g} 2\,(c - v)\,v$$

and the efficiency,

$$(3) \qquad = \frac{Q\,m}{g}\,\frac{2\,(c - v)\,v}{Q\,m\,h}$$

where h is the head back of jet; hence efficiency

$$= \frac{2}{g}\left\{\pm\frac{\sqrt{2\,g\,h}}{h}\,v - \frac{v^2}{h}\right\} \text{ or}$$

$$(4) \qquad z = \frac{2}{g}\left\{\pm\sqrt{\frac{2\,g}{y}}\;x - \frac{x^2}{y}\right\}$$

When y is a constant and $= h^1$

$$(5) \qquad z = \frac{2}{g}\left\{\pm\sqrt{\frac{2\,g}{h^1}}\;x - \frac{x^2}{h^1}\right\}$$

So that a cross-section of the surface parallel to XZ plane is a parabola convex upward. The limiting cases are for $h^1 = o$, when the parabola becomes the Z axis; and for $h^1 = \infty$, when it is a straight line at infinity parallel to X axis. When

$$x = \frac{\sqrt{2\,g\,h}}{2},\ z = 1.$$

Again, when x is constant and $= S$

$$(6) \qquad z = \frac{2}{g}\left[\sqrt{\frac{2\,g}{y}}\,S - \frac{S^2}{y}\right]$$

or

$$(7) \qquad z^2 + \frac{4\,S^2}{y\,g}\left(z-2\right) + \frac{4\,S^4}{g^2}\,\frac{1}{y^2} = 0$$

$$\frac{d\,z}{d\,y} = \frac{2}{g}\left[+\frac{S^2}{y^2} - \frac{\sqrt{2\,g}\,S}{2\,y^{\frac{3}{2}}}\right]$$

Put

$$\frac{d\,z}{d\,y} = 0$$

then

$$y_m = \frac{2\,S^2}{g}$$

for maximum efficiency.

Substituting this value of y_m in (6), $z = 1$.

If $$y = 0,\ \frac{d\,z}{d\,y} = \infty$$

therefore, at the origin the tangent to the curve is vertical. If

$$y = \infty,\ \frac{d\,z}{d\,y} = 0$$

therefore, at infinity the curve becomes horizontal. If $z = 0$, $y = \infty$, or else

$$y = \frac{S^2}{2\,g}$$

Thus the section parallel to the $Z\,Y$ plane is a curve whose zero value occurs at

$$y = \frac{S^2}{2\,g}$$

whose maximum value occurs at

$$y = \frac{4\,S^2}{2\,g}$$

and whose zero value again occurs at infinity.

The equation to the curve is of form

$$z + \frac{C}{y}\,(z-2) + \frac{C^1}{y^2} = 0$$

and a point of inflection occurs for a value of

$$y = \frac{32\,S^2}{9\,g}.$$

If z be made constant,

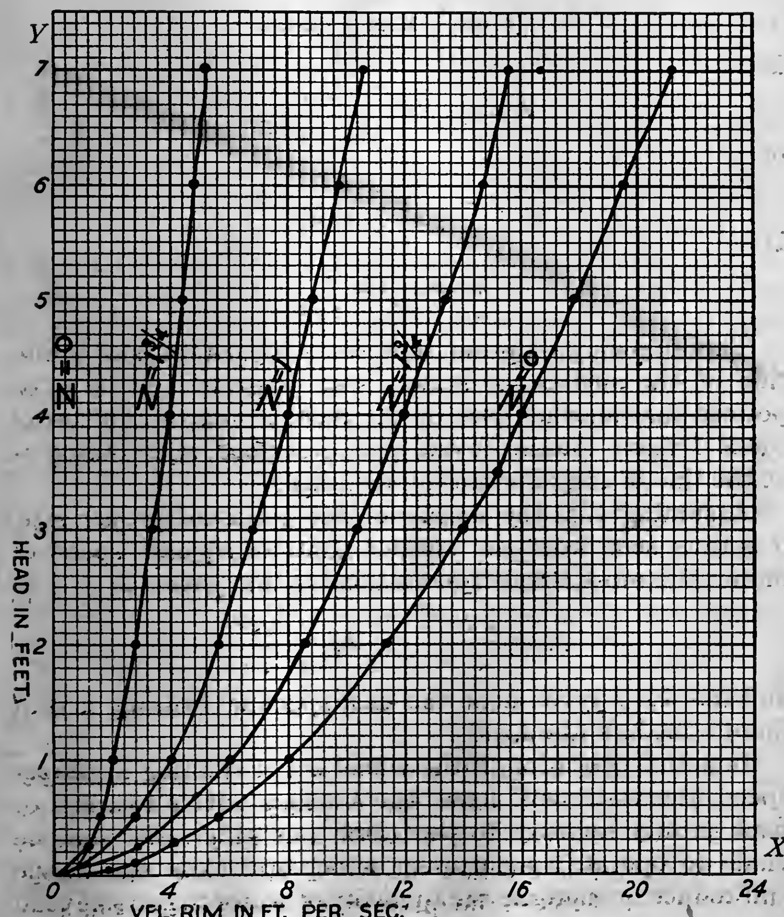
$$z = K = \frac{2}{g}\left(x\sqrt{\frac{2\,g}{y}} - \frac{x^2}{y}\right)$$

or,

$$\frac{g^2}{4}K^2 + g\,(K - 2)\,\frac{x^2}{y} + \frac{x^4}{y^2} = 0$$

or,

$$y = \frac{2\,x^2}{g\,(2 - K \pm 2\sqrt{1 - K})}$$



Giving different values to K, we determine the horizontal contours of the efficiency surface. They will be parabolæ, two in each horizontal plane on the right-hand side of the $Z\ Y$ plane, tangent to each other and to the X axis at the origin and extending in the same direction; because for $o < K \leqq 1$

$$2 - K \pm 2\sqrt{1 - K} > o$$

If

$$K = o,\ y = \frac{x^2}{2 \times 32{\cdot}2}$$

and

$$y = \frac{x^2}{o} \text{ (the } Y \text{ axis).}$$

If

$$K = \tfrac{1}{2},\ y = \frac{2\,x^2}{32{\cdot}2 \times {\cdot}086}$$

or

$$y = \frac{x^2}{32{\cdot}2 \times 2{\cdot}914}$$

If

$$K = 1,\ y = \frac{2\,x^2}{32{\cdot}2}$$

The following diagram represents the contours of a portion of the surface, to scale. [See diagram.] It is to be noticed that another part of the surface lies on the left of the $Z\ Y$ plane similar to the part described, and joining it at the line of singularities at the origin.

Assuming that the nozzle for the jet is of proper size, it is thus seen from the surface that for a given speed of motor, the most advantageous head is that given by

$$y_m = \frac{2\,S^2}{g} \qquad h_{ft.} = \frac{2\,S^2}{g}$$

and that for a given head the best speed of running is that due to one-half the head.

In actual operation, if the wheel is not running at proper speed, the water will leave the buckets with a forward or back motion relative to the earth, and this water may be made to operate a mechanism which will close the nozzle and reduce or increase the quantity of water to suit the load.

on the wheel. Or, again, the wheel may operate a governor, which will open or close a valve in the supply pipe, and so increase or decrease head controlling the jet.

From the formula

$$h = \frac{2\,S^2}{g}$$

it would seem that the theoretically best head for a given speed, with proper nozzle, to which the throttle should work would be

$$\frac{S^2}{16 \cdot 1}$$

A photograph of a plaster model representing the above surface is submitted.

The results of a series of experiments, made on a 12-inch wheel in the engineering laboratory of Purdue University, were platted as points of efficiency on the "speed-head" ($X\ Y$) plane, and the points of equal efficiency joined by contour lines. These contours indicate a surface, like in general form to the theoretical surface, but its section of constant head (a parabola) has its maximum ordinate only about seven-tenths that of the corresponding section of the theoretical surface.

NOTES AND COMMENTS.*

THERMO-ELECTRIC BATTERIES.

In the *American Electrician* of April, Mr. C. J. Reed gives an interesting discussion of the principles involving the direct production of electricity from the combustion of fuel. The accompanying abstract of this paper appears in the *Electrical World:*

The paper is a summary of the principles of the thermo-electric battery; the various types are classified and some of the more important ones considered in detail. Thermo-electric batteries are divided into two general classes: those not containing electrolytes, or those in which no chemical action takes place, and those containing an electrolyte, or those in which the passage of an electric current causes electrolysis or chemical action. The difference between these types is so great that those belonging to the second class have frequently been mistaken for galvanic batteries; this latter type is said to have comparatively a very high possible efficiency, both on account of high

* From the Secretary's monthly reports

thermo-electric power, and of the fact that the chemical or electrolytic reactions may be used to advantage to oxidize fuel within the thermo-electric circuit, its energy being added to the circuit. The Archereau and Jacques cell belongs to the second class; while great claims have been made for the efficiency of this cell, its commercial utility will depend more upon the labor and cost of renewing the electrolyte, carbon and iron pots, and of the convenience and adaptability, than upon its efficiency. Of the Case cell, it is stated that the energy concerned in the chemical reactions takes no part whatever in the production of the electric energy; any chemical reaction which evolves energy must, on reversing, absorb the same amount of energy, and any chemical reaction which absorbs energy must, on reversing, evolve the same amount of energy; the supposition that the chemical action in this cell contributes in any way to the production of the electrical energy involves the admission that an isolatad body of matter is capable of absorbing external heat at a low temperature and evolving it without loss at a higher temperature, which is impossible, since it implies the possibility of perpetual motion. The conclusion arrived at is that a study of the thermo-electric properties of bodies heretofore examined gives little or no reason to hope that this method will ever be preferred for the transformation of energy on a large scale, except through the discovery of new chemical elements having properties radically different from the properties of any known substance; while there is undoubtedly a possibility of such a discovery, the probability is not encouraging.

ACETYLENE GAS IN PHILADELPHIA.

The Philadelphia Fire Underwriters' Association has decided to grant permission for the use of acetylene gas in liquefied form under pressure for lighting purposes, provided that the pressure of gas on the piping in the building to be assured shall at no time exceed one-quarter pound per square inch, and that the cylinder containing the liquefied gas under pressure and all pressure-reducing and safety devices be located outside of such building, and in a separate building well ventilated to the outer air, but of sufficient strength to protect the apparatus from outside interference and from the weather (especially the sun's rays); and that the supply pipe for the building be provided with a hand valve just inside of the building assured, so that the gas may be entirely shut off from such building. It is also provided that the cylinder containing the liquefied gas under pressure shall be equipped with a safety valve to protect against both excessive pressure and unusual increase of temperature, and that both the pressure-reducing and the safety (mercury) valves shall be provided with vent pipes opening into the outer air; and that no acetylene gas or calcium carbide shall be stored on the premises.

THE MINERAL PRODUCTION OF GERMANY IN 1896.

The *Engineering and Mining Journal* publishes the following summary of the more important items of the mineral product of Germany for 1896, as compared with the previous year, viz.:

		1895.	1896.	Changes.	Per cent.
Coal	Metric Tons	79,169,276	85,639,861	Inc. 6,470,585	8·2
Brown Coal (lignite)	"	24,788,363	26,797,880	Inc. 2,009,517	8·1
Petroleum	"	17,051	20,395	Inc. 3,344	19·6
Rock Salt	"	686,940	755,833	Inc. 68,893	10·0
Kainit	"	680,174	856,290	Inc. 176,116	25·8
Other potash salts	"	841,748	924,140	Inc. 82,392	9·8
Iron ores	"	12,349,600	14,162,315	Inc. 1,812,715	14·7
Zinc ores	"	706,423	729,872	Inc. 23,449	33·1
Lead ores	"	161,614	154,660	Dec. 6,954	38·7
Copper ores	"	633,354	717,306	Inc. 83,952	13·3
Gold and silver ores	"	10,845	18,487	Inc. 8,358	77·4
Cobalt, nickel and bismuth ores	"	5,180	4,087	Dec. 1,093	21·0
Iron pyrites	"	127,036	124,950	Dec. 2,086	1·6

The year was evidently one of great activity, all the important products showing increases of considerable importance. The most valuable of the potash salts reported in 1896 were 174,515 tons of chlorate of potash and 71,958 tons of Glauber salts. The principal iron-ore-producing districts last year were Elsass-Lothringen, 4,841,633 tons; Luxemburg, 4,758,741 tons; Bonn, 2,680,889 tons; Breslau (Silesia), 529,602 tons.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 19, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 19, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 110 members and visitors.

Additions to membership since last report, 24.

Mr. Charles James was elected to the Committee on Science and the Arts, to fill the unexpired term of Prof. Arthur Beardsley, resigned.

The Secretary, by instruction from the same committee, reported an abstract from the committee's record in the case of Thomas Shaw's gunpowder tester, referred for investigation by the Institute at its stated meeting of June 21, 1893.

Consideration of the report was deferred until the stated meeting of June.

Lieut. Geo. A. Squier, U.S.A., presented a communication on "The Synchronograph, a New Method of Rapidly Transmitting Intelligence." This system is the joint invention of Lieutenant Squier and Prof. A. C. Crehore, Dartmouth College, Hanover, N. H., and involves a novel and ingenious application of the alternating current. By this system, the speed of telegraphic transmission is said to be enormously increased over that of all methods hitherto devised.

The meeting then proceeded to the continuation of the discussion of "The Smoke Nuisance and its Regulation," deferred from the stated meeting of April 21st.

The following gentlemen participated in the debate, viz.: Mr. H. H. Suplee, Mr. Geo. S. Strong (New York), Mr. J. H. Sternbergh (Reading, Pa.), Dr. Coleman Sellers, Mr. Wm. A. Ingham, Mr. Washington Jones, Mr. Wm. Trautwine, Mr. Arthur Falkenau, Mr. P. A. B. Winand, Prof. H. W. Spangler and Dr. Wm. H. Ford.

Mr. A. E. Outerbridge, Jr., closed the discussion, and offered the following preamble and resolutions:

WHEREAS, The Board of Health of the City of Philadelphia has requested the Franklin Institute to investigate the question of smoke prevention and to offer practical suggestions relative thereto; and

WHEREAS, The use of bituminous coal for fuel is increasing in this city, and is likely so to continue in the future; and

WHEREAS, It appears from testimony of scientists and expert mechanics, presented at this meeting, by invitation of this Institute, that it is practicable to burn bituminous coal in stationary boilers and furnaces without creating a smoke nuisance; therefore, be it

Resolved, That it is the sense of this meeting that the continuous or frequent discharge of dense black smoke from the combustion of bituminous coal is unnecessary, and should not be permitted within the city limits.

Resolved, That a copy of these resolutions be sent to the Mayor, to the President of the Board of Health, and to the Presidents of City Councils.

These were discussed by Messrs. H. F. Colvin, Spencer Fullerton, Samuel M. Vauclain, William R. Fisher and Max Livingstone, and, on motion, were referred to the Board of Managers, with the request to report thereon at the next stated meeting of the Institute.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held May 5, 1897.*]

MR. JAMES CHRISTIE in the chair.

REPORTS on the following subjects passed first reading:

Williams' Typewriting Machine, Williams Typewriter Co., New York.

Rotary Steam Engine, Samuel T. Lewis, Philadelphia, Pa.

Gear-Moulding Machine, Samuel Groves, Pittsburgh, Pa.

Automatic Fluid-Pressure Friction Clutch, George M. Richards, Erie, Pa.

Automatic Safety Device for Electric Circuits, Lewis G. Rowand, Camden, N. J.

Window Ventilator, Percy A. Sanguinetti.

Screens for Photo-Mechanical Engraring, Louis E. and Max Levy.

Metallic Corner Bead, Edward B. Marsh, Lexington, Mass.

Proposition for the Trisection of the Angle, Chas. Morrell, Chicago, Ills.

Flying Machine, Praull Aëromotor Co., Phila.

Investigations in the Molecular Physics of Cast Iron, A. E. Outerbridge, Jr.

REPORTS on the following subjects were adopted:

Knife-Sharpening Attachment for Sewing Machines, Mary H. P. Cox, Kirkham, Md.

U. S. Letters-Patent No. 577,127, February 16, 1897.

ABSTRACT.—The device is a clamp adapted to be attached to the table of a sewing machine, supporting an extensible post upon which is a bearing carrying a shaft. On one end of this shaft is a friction pulley, intended to engage with the fly-wheel of the machine, and on the other end an emery wheel. When the attachment is in position on a sewing machine, and the fly-wheel is started by the treadle, the emery wheel will grind anything applied to it.

The report finds that the invention has been substantially anticipated. [*Sub-Committee.*—G. Morgan Eldridge, Spencer Fullerton and John Haug.]

Battery Motor.—A. A. Kent, Worcester, Mass.

ABSTRACT.—This invention is a series-wound motor, the field winding of which is so arranged that an increased number of turns of wire can be added when the machine is used as a dynamo, so as to increase the strength of the field. The armature, which is the part of the machine which it is claimed has special features, is made of cast iron, with projecting poles. The number of these poles, it is claimed, reduces the friction of the bearings.

The report finds that this feature is shown, and in a more marked degree than in this particular design, in the Gramme ring, Siemens drum, or Pacinotti type of armature; that the motor embodies no special features that are new in the art; and that motors of higher efficiency have been built and are on the market. [*Sub-Committee.*—C. J. Reed, Thos. Spencer, Wm. C. L. Eglin, W. Sonneberg.]

Rotary Steam Engine.—Samuel T. Lewis, Philadelphia, Pa.

ABSTRACT.—A central disk is furnished with slots, in which move slides or pistons having projections. It has also a hub, through which is an opening for a shaft. It is surrounded by a casing containing steam ports and an exhaust port. On top of the casing is a steam chest having a slide valve for steam admission to the several steam ports, and for reversing the engine. On each side of the disk is a casing in two sections, which form a circular space with separate pistons in them. Steam ways or ports are in the outside casing and connect with the separate divisions on each side. The pistons travel with the disk in its movement, and the object of the several steam ways is to use steam expansively, by allowing it to flow out by one or more of them at one time.

The report finds that while much ingenuity is displayed in the machine, it is very complicated, and would be so wasteful in the use of steam as to be practically valueless. [*Sub-Committee.*—H. F. Colvin, J. M. Emanuel, Spencer Fullerton.]

Automatic Disinfectant Ejector.—Wm. B. Hollingshead, Bronxville N. Y.

Abstract.—This device consists of a receptacle for a disinfecting liquid of any kind intended to be placed in communication with the flush pipe of a sink, etc., and the construction is such that every time the flush is operated a small quantity of the disinfecting liquid is caused, automatically, to be ejected from the reservoir and to mingle with the flush-water as it passes to the sink. For the mechanism of the device reference is made to U. S. Letters-Patent No. 510,389, December 5, 1893.

The report finds that the device cannot be depended upon to remain in serviceable condition for any length of time, because of the liability of obstruction and the difficulty of detecting the stoppage and of cleaning the tube when the obstruction is discovered. [*Sub-Committee.*—Henry R. Heyl, John G. Bullock.]

Following is a list of applications received for investigation by the Committee, since April 22, 1897:

No. 1971. Crehore and Squier's Synchronograph. Application filed May 8.
" 1972. Willard & Frick's Time Recorder. Application filed May 20.
" 1973. Arndt's Econometer. Application filed May 21. W.

SECTIONS.

Cheimcal Section.—Stated meeting, Tuesday, May 18th, Dr. Joseph W. Richards in the chair.

Mr. Waldron Shapleigh, Chemist to the Welsbach Company, presented some "Notes on Lucium." (To be published.)

Messrs. C. T. Mixer and H. W. Dubois presented some "Notes on the Determination of Insoluble Phosphorus in Iron Ores." (To be published.)

Dr. Harry F. Keller, for himself and Philip Maas, described "Some New Derivatives of Diacetyl." (To be published.)

Electrical Section.—The card of the stated meeting of Tuesday, May 25, contains the following items:

"Electric Elevators," by Mr. Joseph Sachs, New York. "Exhibition of, and Discussion upon, Rheostats." Discussion to be opened by Mr. C. E. Carpenter, Ward Leonard Electrical Company, New York.

Mining and Metallurgical Section.—Stated meeting, Wednesday, May 12th, Mr Benj. Smith Lyman in the chair.

The Section adopted a set of rules for its government.

The following permanent officers were elected: President, Benj. Smith Lyman; Vice-Presidents, Dr. D. K. Tuttle, A. E. Outerbridge, Jr.; Secretary, Wm. C. Henderson; Conservator, Dr. Wm. H. Wahl; Committee on Finance, Messrs. Henry G. Morris, Joseph Richards; Committee on Papers, Messrs. F. L. Garrison, Charles James and C. J. Reed.

Professor Garrison read a paper on "Underground Water Supply," which evoked considerable discussion. (To be published.) W.